DAVID SAMUELSON'S

'HANDS-ON'
Manual for Cinematographers

[redacted]

David Samuelson's

'Hands-on' Manual for Cinematographers

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Books by the same Author:

Motion Picture Camera and Lighting Equipment
Published by Focal Press
First published 1977, second edition 1986

Motion Picture Camera Techniques
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First published 1978, second edition 1984

Motion Picture Camera Data
Published by Focal Press
First published 1979

The Samuelson Manual of Cinematography
Published by The Samuelson Group, plc
First published 1980

Panaflex Users' Manual
Published by Focal Press
First published 1990

Computer programs by the same Author:

1984:
The Cinematographers' Computer Program for TRS-80 Model 100 and NEC 8201A Portable computers.
Published by Panavision Inc.

1987:
The Panavision Cinematographers' Computer Program for the Sharp PC-1360 Pocket computer.
Published by Panavision Inc.

(In 1987 David W. Samuelson and William B. Pollard each received ACADEMY TECHNICAL ACHIEVEMENT AWARDS from the Academy of Motion Picture Arts and Sciences for the CINEMATOGRAPHERS' COMPUTER PROGRAM.)

1990:
The Cinematographers' Computer Program for the Sharp 7000/8000/9000 Series Organizers.
Published by dSam Ltd.

The dSam Cine-Photo-Video Computer Calculator series of computer programs are published by dSam Ltd., 7, Montagu Mews West, London W1H 1TF, UK.

Depth of Field Calculators by the same Author:

1972:
Samcine Depth of Field Calculator.
Published by Samuelson Film Service Ltd.
Designed in association with W.B. Pollard.

1974:
Samcine Mk.II Depth of Field Calculator.
Published by Samuelson Film Service Ltd.
Designed in association with W.B. Pollard.

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David Samuelson's

'HANDS-ON'

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FOREWORD BY FREDDIE YOUNG

To all Directors of Photography, Operators, Focus Pullers and Clapper Loaders, David Samuelson's *'Hands-On' Manual for Cinematographers* gives a wealth of information on practically every problem one might wish to look up for all the latest knowledge of technical matters in the field of cinematography.

This must be the most extensive and comprehensive manual ever put together in such a concise way to make it possible to quickly find the answer to anything one might want to check.

I thoroughly recommend it for your library and I must congratulate David for what must have been a long and most painstaking undertaking.

Freddie Young B.S.C.

Freddie Young O.B.E., B.S.C.
Cinematographer
Winner of three Academy Awards for Cinematography for photographing
Lawrence of Arabia, Dr Zhivago, and *Ryan's Daughter*

FOREWORD BY HERB LIGHTMAN

When, some ten years ago, or more, David Samuelson casually mentioned to me that he had begun writing an in-depth, 'hands-on' manual for cinematographers, I had no doubt that the finished product would be something quite special, for he was already the published author of several widely acclaimed books on various aspects of cinematography.

And so, I waited - and *waited*. The gestation period of this manuscript made elephants seem like speed demons. But now that I actually hold the completed work in my hands, I can say most enthusiastically that it was well worth the wait, for it provides the cinematographer with just about every bit of technical information he or she might possibly need before, during and after the shoot.

To understand why the creation of this manual took so long and is, in effect, a virtual encyclopedia of cinematographic know-how in one complete handbook, one needs to know a bit about the author.

At a very early age David Samuelson began an illustrious career as one of Britain's top cameramen. Later, as a founding director and technical chief of Samuelson Film Service Ltd., he produced a steady stream of inventions and innovations pertinent to motion picture filming equipment, among them the first compact through-the-lens video assist, the remote control pan and tilt head (which was his major contribution to the Louma camera crane) and the cinematographer's pocket computer calculator. Several of these achievements have merited awards from Hollywood's Academy of Motion Picture Arts and Sciences.

Like the late, great industrial designer, Raymond Loewy, who said of himself that he 'never let well enough alone', David Samuelson worked constantly to make motion picture equipment better and better. Over the years he suggested so many progressive modifications to Panavision equipment that the company made him their valued consultant - a post which he still holds to this day.

I first met David Samuelson when I began what turned out to be a very long tenure as Editor of *American Cinematographer*. As a constant contributor of technical articles throughout the period, he was a veritable fountainhead of information on state-of-the art developments within the industry. Ultimately, his monthly feature, *Talking Technically*, became an eagerly awaited and much appreciated element of the Journal.

His manual reads like what it is: a cameraman talking to cameramen - but lest anyone imagine that he might possibly be simply a theorist on the subject, I should like to say that I have had the pleasure and privilege of observing him in action when both of us worked side-by-side as cameramen on the official films for four Olympic Games.

Filming intricate, high speed sports action with lenses as long as 2,000mm, when there is no possibility of a second take, tends to separate the men from the boys. But David, cool as the proverbial cucumber, unfailingly captured all the peak action - in-focus and perfectly exposed. Watching him operate was a thrill - and an education. (In order to celebrate, after we had filmed the Men's Downhill Championship event at Innsbruck, we both skied the suicidal, solid-ice competition run from top to bottom - and survived!)

So now, *David Samuelson's HANDS-ON MANUAL FOR CINEMATOGRAPHERS* is, at last, a reality - but why was it so long aborning? Simply because of my dear friend and colleague's innate super-perfectionism and meticulous attention to detail: relentlessly researching, testing and re-testing, making his lists and checking them more than twice.

The result is obviously a labor of love and an indispensable companion to everyone - whether film student or most highly experienced Director of Photography - who funnels images through a lens and onto motion picture film.

Herb Lightman
Cinematographer and Director
Editor of *AMERICAN CINEMATOGRAPHER* January 1966 - June 1982

ACKNOWLEDGEMENTS

The technology of cinematography has been the cornerstone of my life and this book is the distillation of a lifetime spent doing it, watching others do it, talking to others who do do it, reading about it, writing about it, asking questions about it, and seeing and enjoying the results.

To all of you I say a big THANK YOU, whatever it is that you taught me along the way is in this book, somewhere.

I am particularly obliged to John Farrand, CEO of Panavision Inc., for permission to reproduce many illustrations originally created for the *Panaflex Users' Manual*, to Sydney Samuelson and Brian Smith for permission to reproduce many illustrations originally created for the *Samuelson Manual of Cinematography* which I wrote as a part of the Samuelson Film Service Ltd. catalogue and to Wally Gentleman for permission to use material he wrote more than thirty years ago on the use of stock background plates.

More recentlly, while writing and checking this book I have been it touch with (among others too numerous to recall) and am grateful to:

Jeff Allen, Warren Bass, Alan Bermingham, Mike Boudray, Neville Bradbury,
Stuart Brock, Robin Browne, Denny Clairmont, John Croft, Jacques Durand,
Jonathan Erland, Abbie Ewan, John Fauer, Ken Fisher, John Grainger,
Gerry Hirschfeld, Tony Iles, Conrad Kiel, Karl Kelly, Dennis Kimbley,
Herb Lightman, Rowland Little, Harry Mathias, Mike Milne-Smith,
Tak Myagashima, Patrick Neale, Iain Neil, Elmer Nyiri, Alan Piper, Clive Potter,
Bob Quinn, Brian Rose, John Rosetti, Eric Rudolph, Eddie Ruffell,
Adam Samuelson, Michael Samuelson, Ira Tiffin, John Vennables,
Hugh Whittaker, Michael Winter, Paul Witz, Bill Woodhouse, Corrie van Wyk,
Freddie Young.

To all those who are not on the above list, but should be, my apologies.

ABOUT THE AUTHOR

David Samuelson was born in London in 1924, the eldest son of pioneer film producer G.B. Samuelson. He entered the British film industry in 1941 and has been a projectionist, a cutting room assistant, a film cameraman, a facilities company executive, a consultant on the technology of film making, a computer program writer and an author and lecturer on the subject of film production technology.

He is a Fellow of the Royal Photographic Society, a Fellow of the British Kinematograph, Sound and Television Society, a Fellow of the Society of Motion Picture and Television Engineers, a Member of the British Society of Cinematographers and an Associate Member of the American Society of Cinematographers.

He was awarded the Special Commendation Award of the SMPTE for 'Outstanding Contributions to Motion Picture Technology' in 1978, the Presidential Proclomation Award of the SMPTE for 'Continued support of the Industry on an International level and for his long standing contributions as a Writer and a Lecturer' in 1984, an Academy Scientific and Engineering Award of the AMPAS for the 'Development of the Louma Camera Crane and Remote Control System for Motion Picture Production' in 1980, an Academy Technical Achievement Award for the 'Development of the Cinematographers' Computer Programs' in 1987, the Journal Award of the BKSTS in 1984 and the UNIATEC 'Prix de Literature Technique' in 1975.

Original inventions and developments include the video viewfinder for film cameras, the remote control pan and tilt head which was a part of the original Louma Camera Crane system, the Samcine Depth of Field calculator, the Samcine Inclining Prism, the Mitchell BNC/Front Projection conversion and the dSam Cinematographers' Computer Calculator.

As a film cameraman he has filmed in more than 40 countries and filmed four Olympic Games and two World Cup Soccer events and has lectured on various aspects of Motion Picture Technology in Britain, France, Sweden, Denmark, Italy, Czechoslovakia, Poland, the former U.S.S.R., Israel, South Africa, China, Hong Kong, Japan, Philippines, Australia, Canada and the U.S.A.

INTRODUCTION

For the Introduction of my book Motion Picture Camera Techniques, published in 1978, I wrote the following:

> Without a doubt, the most important ingredient of a successful film is a good screenplay. Only after this does the application of men, money and machinery to translate the pages of the script into scenes in a film become significant.
>
> Film making combines many aspects. It is creative and yet it is bound by technology, standards and tradition. Individuals make contributions which leave an indelible stamp upon the production, and yet it is essentially a team effort. Masterpieces were made with equipment of yesteryear, yet new equipment, new materials and new techniques make new concepts, previously beyond the immagination, possible to achieve. There are new limits - but even these rules are there to be broken. People can make good names for themselves, reputations may be ruined by the maladroitness of others and, ironically, the most important person to be satisfied may have nothing to do with the project in hand but be the person who is prepared to finance a future production on the strength of the current one.
>
> Cinematography is an art; of that there is no doubt. But the canvas is expensive and unless commercial viability is observed at all stages, he who is prodigal or avaricious faces the possibility of a lifetime of frustration. There is no-one more sorrowful than an unemployed film maker, especially one who has exceptional talent and motivation but whom no one can afford to employ. It must never be forgotten that films are made with some one else's money and respect for this may well affect an individual's continuity of employment.
>
> Rarely is there an opportunity for undisciplined experiment for, invariably, there is too much money at stake, putting expertise at a premium. A bold imagination, the very life blood of cinema and necessary for its survival, may only be indulged if the results are virtually guaranteed, for failure is too costly to contemplate.
>
> What then should be the aim? What is good and what is worthwhile?
>
> If the end result satisfies only its creators it is merely an ego trip. If it succeeds in recouping its costs and feeds. clothes and warms those who work on it and even makes a profit for re-investment in another film and the regeneration of the film industry then it is successful indeed. Film makers should never underestimate the importance of money or lose their respect for it, particularly if it belongs to another person.

The then President of the SMPTE, the late Bill Heddon, honored me in the review he wrote by saying that these words should be carved in stone and set into the portals of every school of film learning in the land.

Today, some fifteen years later (other than to add an 'or she' to each 'he') I find it impossible to add or to improve upon what I said then.

David W. Samuelson, March 1994

1 ADDRESSES

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1 ADDRESSES

The following is a listing of addresses, phone and fax numbers of current motion picture camera, filmstock and video camera manufacturers. It is not intended as a directory of suppliers but rather as a resource as to where help, information and items can be obtained.

Where a company is listed only in one country and not under the country where information or help is required the user can be sure that a phone call or a fax to the company listed will produce the local phone and fax numbers.

In the phone and fax numbers listed below, International Direct Dialling codes are shown in parentheses (i.e. (1) for the U.S.A.) and local area dialling codes are shown before the hyphen (i.e. 213- for the Los Angeles area). In some instances a 0 may have to be added to the start of a number when dialling locally.

1.1 FILM CAMERA MANUFACTURERS

COMPANY	ADDRESS	COUNTRY	PHONE
Aäton SA	2 rue de la Paix B.P. 104 F-38001 Grenoble	France	Tel: (33) 76-42 6409 Fax: (33) 76-51 3491
Aäton Des Autres Inc.	4110 W.Magnolia Blvd. Burbank, CA 91505	U.S.A.	Tel: (1) 818-972 9078 Fax: (1) 818 972 2673
Alan Gordon Enterprises Inc.	1430 Canuhenga Blvd. Hollywood, CA 90028	U.S.A.	Tel: (1) 213-466 3561 Fax: (1) 213-871 2193
Arnold & Richter GmbH	Türkenstraße 89 D-8000 München 40	Germany	Tel: (49) 89-3809-1 Fax: (49) 89-3809-244
Arri (GB) Ltd	1-3 Airlinks Spitfire Way, Heston Middx, TW5 9NR	U.K.	Tel: (44) 81-848 8881 Fax: (44) 81-561 1312
Arriflex Corporation	500 Route 303 Blauvelt, NY 10913-1123	U.S.A.	Tel: (1) 914 353 1400 Fax: (1) 914 425 1250
	600 N. Victory Blvd. Burbank, CA 91502-1639		Tel: (1) 818-841 7070 Fax: (1) 818-848 4028
Bolex International S.A.	15 Route de Lausanne CH-1400 Yverdon	Switzerland	Tel: (41) 24-216 021 Fax: (41) 24-216 871
Fries Engineering Inc.	8743 Shirley Avenue Northridge, CA 91324	U.S.A.	Tel: (1) 818-998 5400 Fax: (1) 818-998 7553
Moviecam F.G. Bauer GmbH	Auhofstraße 254 A-1130 Wien	Austria	Tel: (43) 222-826 9380 Fax: (43) 222-829 4681
NAC Inc.	2-7 Nishi-Azabu 1-Chome Minato-ku Tokyo	Japan	Tel: (81) 3 3404 2321 Fax: (81) 3 3479 2402
NAC International IMC Ltd.	Wellington House, Wellington Street Thame, Oxon OX9 3BW	U.K.	Tel: (44) 844 261 733 Fax: (44) 844 261 736
NAC Visual Systems	Warner Centre 6307-K de Soto Avenue Woodland Hills, CA 91367	U.S.A.	Tel: (1) 818 313 9205 Fax: (1) 818 313 9122
Panavision International Inc.	18618 Oxnard St. Tarzana, CA 91357	U.S.A.	Tel: (1) 818-881 1702 Fax: (1) 818-342 8166
Panavision U.K. Ltd.	Wycombe Road, Wembley Middx, HA0 1QN	U.K.	Tel: (44) 81-902 3473 Fax: (44) 81-902 3473
Photo-Sonics	820 South Mariposa St. Burbank, CA 91506	U.S.A.	Tel: (1) 818-842 2141 Fax: (1) 818-842 2610

1.2 FILMSTOCK MANUFACTURERS

The types of filmstock available from the manufacturers and their specifications are constantly changing. It seems that almost every month or so, one or other of the manufacturers introduces a new emulsion and/or discontinues an old one. This makes it very difficult for a manual such as this to keep up-to-date unless it is revised and republished at least once a year.

While the data published in Section 11 was current at the time of going to press there is no saying if that will be so the day following. When in doubt it is better to telephone or fax the manufacturers for the very latest information

COMPANY	ADDRESS	COUNTRY	PHONE
Agfa-Gevaert N.V.	Septestraat 27 B-2640 Mortsel, Antwerp	Belgium	Tel: (32) 3-444 8041 Fax: (32) 3-444 7094
Agfa-Gavaert SA	274-276 Avenue Napoleon Bonepart Boit Postale 301 92506 Rueil Malmaison	France	Tel: (33) 14-732 7111 Fax: (33) 14-732 7099
Agfa-Gavaert AG	Postfach D-5090 Leverkusen 1	Germany	Tel: (49) 214-304 742 Fax: (49) 214-304 449
Agfa-Gavaert Japan Ltd.	8-1 Higashiyama 3-Chome, Meguro-ku Tokyo 153	Japan	Tel: (81) 3-5704 3145 Fax: (81) 3-5704 3083
Agfa-Gevaert Ltd.	27 Great West Road Brentford, Middx.	U.K.	Tel: (44) 81-560 2131 Fax: (44) 81-231 4947
Agfa Corporation	100 Challenger Road Ridgefield Park NJ 07660	U.S.A.	Tel: (1) 201-440 2500 Fax: (1) 201-342 4742
	1801 Century Park East Suite 110 Los Angeles, CA 90028		Tel: (1) 310-552 9622 Fax: (1) 310-203 9672
Eastman Kodak Company	343 State St. Rochester, NY 14650	U.S.A.	Tel: (1) 716-724 4000 Fax: (1) 213-464 5886
	6700 Santa Monica Blvd. Hollywood, CA 90038		Tel: (1) 213-464 6131 Fax: (1) 213-464 5886
Kodak-Pathé	8-26 rue Villot 75594 Paris Cedex 12	France	Tel: (33) 14-001 3000 Fax: (33) 14-001 4650
Kodak AG	Hedelfinger Strasse Postfach 369 7000 Stuttgart 60	Germany	Tel: (49) 711-406 0 Fax: (49) 711-406 2614
Kodak Ltd.	Station Road Hemel Hempstead Herts HP1 1JU	U.K.	Tel: (44) 442-61122 Fax: (44) 442-844 458
Fuji Photo Film Co. Ltd.	26-30 Nishiazabu 2-Chome, Minato-Ku Tokyo	Japan	Tel: (81) 3-3406 2111 Fax: (81) 3-3406 2173
Fuji Photo Film (Europe) GmbH	Heesenstraße 31 Postfach 190321 D-4000 Düsseldorf 11	Germany	Tel: (49) 211-5089 0 Fax: (49) 211-5089 344
Fuji Photo Film (U.K.) Ltd.	125 Finchley Road London NW3 6HV	U.K.	Tel: (44) 71-586 5900 Fax: (44) 71-722 4259
Fuji Photo Film U.S.A. Inc.	555 Taxter Road Elmsford, NY 10525	U.S.A.	Tel: (1) 914-789 8100 (1) 800-345 6385 Fax: (1) 914-682 4955
	1141 N. Highland Ave. Hollywood, CA 90038		Tel: (1) 213-465 5656 Fax: (1) 213-465 8279
Ilford Ltd.	Town Lane Mobberley, Knutsford Cheshire, WA16 7HA	U.K	Tel: (44) 565 650050 Fax: (44) 61 953 5001
Ilford Photo Corp. U.S.A.	West 70 Century Rd. PO Box 288 PARAMUS, NJ 07652	U.S.A.	Tel: (1) 201-265 6000 Fax: (1) 201-587 1620

1.3 VIDEO CAMERA MANUFACTURERS

COMPANY	ADDRESS	COUNTRY	PHONE
BTS Broadcast Television Systems SRL	Theale Close, Calcot, Reading Berks. RG3 7SD	U.K.	Tel: (44) 734 302 834 Fax: (44) 734 303 123
Hitachi Denshi (U.K.) Ltd.	13-14 Garrick Ind. Centre Irving Way Hendon, NW9 6AQ	U.K.	Tel: (44) 81 202 4311 Fax: (44) 81 202 2451
Ikegami Tsushinki Co., Ltd.	5-6-16 Ikegami, Ohta-ku Tokyo 146	Japan	Tel: (81) 3 5700 1111 Fax: (81) 3 5700 1137
Ikegami Electronics (Europe) GmbH	Ikegami Straße 1 4040 Neuss 1	Germany	Tel: (49) 02101 123 0 Fax: (49) 02101 102820
Ikegami Electonics (U.S.A.), Inc.	37 Brook Ave. Maywood, NJ 07607	U.S.A.	Tel: (1) 201 368 9171 Fax: (1) 201 569 1626
Ikegami Electronics U.K.	Kestrel Ct., Pound Road Chertsey, Surrey KT16 8ER	U.K.	Tel: (44) 932 568 966 Fax: (44) 932 569 637
JVC: Victor Company of Japan	8-14 Nihonbashi-Honcho, 4-Chome Chuo-Ku Tokyo 103	Japan	Tel: (81) 3 3241 7811 Fax: (81) 3 3245 1402
JVC Professional Products (U.K.) Ltd.	Alperton House, Bridgewater Road Wembley Middx. HA0 1EG	U.K.	Tel: (44) 81 902 8812 Fax: (44) 81 900 0941
JVC Professional Products Company	41 Slater Drive Elmswood Park, NJ 07407	U.S.A.	Tel: (1) 201 794 3900 Fax: (1) 201 523 3601
NEC (UK) Ltd.	1 Victoria Road London W3 6UL	U.K.	Tel: (44) 81 993 8111 Fax: (44) 81 992 7161
Panasonic: Matushita Electric Industrial Co., Ltd.	2-15 Matsuba-cho Kadoma City, Osaka 571	Japan	Tel: (81) 6 901 1463 Fax: (81) 6 905 1522
Panasonic Broadcast Europe	107-109 Whitby Road Slough, Berks. SL1 3DR	U.K.	Tel: (44) 753 692 442 Fax: (44) 753 512 673
Panasonic Broadcast & Television Systems Co.	One Panasonic Way Secausus, NJ 07094	U.S.A.	Tel: (1) 201 348 7975 Fax: (1) 201 348 7511
Sony Corporation	2F, Jakoma Building 1-12-10 Kitashinagawa Shinagawa-ku Tokyo 140	Japan	Tel: (81) 3 3458 7088 Fax: (81) 3 3458 7094
Sony Broadcast & Professional UK	The Heigths Brooklands, Weybridge Surrey, KT13 0XW	U.K.	Tel: (44) 932 816 000 Fax: (44) 932 817 011
Sony Operations & Technical Services	123 W. Tryon Ave. Teaneck, NJ 07666	U.S.A.	Tel: (1) 201 833 5300 Fax: (1) 201 833 5860
Thompson Video Equipment	17, rue du Petit Albi BP 8244 95801 Cergy St. Christophe	France	Tel: (33) 1 3420 7000 Fax: (33) 134 20 70 47
Thompson Broadcast Ltd.	18 Horton Road Datchet, Berks. SL3 9ES	U.K.	Tel: (44) 753 581 122 Fax: (44) 753 581 196
Thompson Broadcast Inc.	49 Smith Street Englewood, NJ 07631	U.S.A.	Tel: (1) 201 569 1650 Fax: (1) 201 569 1511

2 AWARDS AND NOMINATIONS FOR CINEMATOGRAPHY

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2.1 ACADEMY OF MOTION PICTURE ARTS AND SCIENCES, AWARD FOR CINEMATOGRAPHY .... 2 - 2

AWARDS AND NOMINATIONS FOR CINEMATOGRAPHY

To win an 'Oscar' from the Academy of Motion Picture Arts and Sciences for Cinematography is the highest recognition to which feature film Directors of Photography can aspire.

Even to have been nominated for such an award, bearing in mind the number of films eligable each year and that the final choice from the others nominated is often by a very narrow margin, is an outstanding achievement in itself.

The following list of nominations, with the winners printed in capitals, are given in full so that present-day Cinematographers and Film Students seeking to study the great works of Cinematography of the past may have them as a guide, that others of us who watch old films on television should know those who were honoured, that practising Directors of Photography should know their peers, and that junior members of camera crews should know the past achievements of some of their older colleagues.

Note: For the sake of clarity all middle initials and name appendages (Jr., etc) that may have appeared in the original citations have been omitted from the following lists:

2.1 ACADEMY OF MOTION PICTURE ARTS AND SCIENCES, AWARD FOR CINEMATOGRAPHY

JOHN ALCOTT	BARRY LYNDON	1975
Henry Alekan	Roman Holiday	1953 (B&W)
NESTOR ALMENDROS	DAYS OF HEAVEN	1978
Nestor Almendros	Kramer v Kramer	1979
Nestor Almendros	The Blue Lagoon	1980
Nestor Almendros	Sophie's Choice	1982
John Alonzo	Chinatown	1974
JOHN ALTON	AN AMERICAN IN PARIS	1951 (Col)
Arthur Arling	I'll Cry Tomorrow	1955 (B&W)
ARTHUR ARLING	THE YEARLING	1946 (Col)
Joseph August	Portrait of Jennie	1948 (B&W)
Lucien Ballard	The Caretakers	1963 (B&W)
Michael Ballhaus	Broadcast News	1988
Michael Ballhaus	Fabulous Baker Boys	1990
George Barnes	Devil Dancer	1927/28
George Barnes	Magic Flame	1927/28
George Barnes	Sadie Thompson	1927/28
George Barnes	Our Dancing Daughters	1928/29
GEORGE BARNES	REBECCA	1940 (B&W)
George Barnes	Spellbound	1945 (B&W)
George Barnes	The Spanish Main	1945 (Col)
George Barnes	Samson and Delilah	1950 (Col)
Adrian Biddle	Thelma & Louise	1992
Joseph Biroc	Hush...Hush, Sweet Charlotte	1964 (B&W)
JOSEPH BIROC	THE TOWERING INFERNO	1974
PETER BIZIOU	MISSISSIPI BURNING	1989
Ralf Bode	Coal Miners Daughter	1980
JEAN BOURGOIN	THE LONGEST DAY	1962 (B&W)
Charles Boyel	Anchors Aweigh	1945 (Col)
Norbert Brodine	Merrily We Live	1938
Norbert Brodine	The Frogmen	1951 (B&W)
Joseph Brun	Martin Luther	1953 (B&W)
Stephen H. Burham	Hoffa	1993
Robert Burks	Strangers on a Train	1951 (B&W)
Robert Burks	Rear Window	1954 (Col)
ROBERT BURKS	TO CATCH A THIEF	1955 (Col)
Robert Burks	A Patch of Blue	1965 (B&W)
Bill Butler	One Flew Over the Cuckoo's Nest	1975
JACK CARDIFF	BLACK NARCISSUS	1947 (Col)
Jack Cardiff	War and Peace	1956 (Col)
Jack Cardiff	Fanny	1961 (Col)
Gu Changwei	Farewell My Concubine	1994
Michael Chapman	Raging Bull	1980
Michael Chapman	The Fugitive	1994
Charles Clarke	Moontide	1942 (B&W)
Charles Clarke	Hello, Frisco, Hello	1943 (Col)
Charles Clarke	Green Grass of Wyoming	1948 (Col)
Charles Clarke	Sand	1949 (Col)
Wilfred Cline	Aloma of the South Seas	1941 (Col)
CHISLAIN CLOQUET	TESS	1980
William Clothier	The Alamo	1960 (Col)
William Clothier	Cheyenne Autumn	1964 (Col)
Edward Coleman	The Absent Minded Professor	1961 (B&W)
Edward Coleman	Mary Poppins	1964 (Col)
Edward Cronjager	Beneath The Twelve-Mile Reef	1953 (Col)
Stanley Cortez	The Magnificent Ambersons	1942 (B&W)
Stanley Cortez	Since You Went Away	1944 (B&W)
Jack Couffer	Jonathan Livingston Seagull	1973
James Crabe	The Formula	1980
Jordan Cronenweth	Peggy Sue Got Married	1987
Edward Cronjager	Cimarron	1930/31

Edward Cronjager	Sun Valley Serenade	1941 (B&W)
Edward Cronjager	The Pied Piper	1942 (B&W)
Edward Cronjager	To The Shores of Tripoli	1942 (Col)
Edward Cronjager	Heaven Can Wait	1943 (Col)
Edward Cronjager	Home in Indiana	1944 (Col)
FLOYD CROSBY	TABU	1930/31
Dean Cundey	Who Framed Roger Rabbit	1989
William Daniels	Anna Christie	1929/30
WILLIAM DANIELS	THE NAKED CITY	1948 (B&W)
William Daniels	Cat on a Hot Tin Roof	1958 (Col)
William Daniels	How The West Was Won	1963 (Col)
Allen Davey	Bitter Sweet	1940 (Col)
Allen Davey	Hello, Frisco, Hello	1943 (Col)
Allen Davey	Cover Girl	1944 (Col)
Allen Davey	A Song to Remember	1945 (Col)
Allen Daviau	E.T. The Extra-Terrestrial	1982
Allen Daviau	The Color Purple	1986
Allen Daviau	Empire of the Sun	1988
Allen Daviau	Avalon	1991
Allen Daviau	Bugsy	1992
Ernest Day	A Passage to India	1985
Robert de Grasse	Vivacious Lady	1938
PASQUALINO DE SANTIS	ROMEO & JULIET	1968
Caleb Deschanel	The Right Stuff	1984
Caleb Deschanel	The Natural	1985
CLYDE DE VINNA	WHITE SHADOWS IN THE SOUTH SEAS	1928/29
Stuart Dryburghe	The Piano	1994
Elmer Dyer	Air Force	1943 (B&W)
Arthur Edeson	In Old Arizona	1928/29
Arthur Edeson	All Quiet On the Western Front	1929/30
Arthur Edeson	Casablanca	1943 (B&W)
Daniel Fapp	Desire Under the Elms	1958 (B&W)
Daniel Fapp	The Five Pennies	1959 (Col)
Daniel Fapp	One, Two, Three	1961 (B&W)
DANIEL FAPP	WEST SIDE STORY	1961 (Col)
Daniel Fapp	The Unsinkable Molly Brown	1964 (Col)
Daniel Fapp	Ice Station Zebra	1968
Daniel Fapp	Marooned	1969
Gabriel Figueroa	The Night of the Iguana	1964 (B&W)
George Folsey	Reunion In Vienna	1932/33
George Folsey	Operator 13	1934
George Folsey	The Gorgeous Hussy	1936
George Folsey	As Thousands Cheer	1943 (Col)
George Folsey	The White Cliffs of Dover	1944 (B&W)
George Folsey	Meet me in St. Louis	1944 (Col)
George Folsey	The Green Years	1946 (B&W)
George Folsey	Green Dolphin Street	1947 (B&W)
George Folsey	Million Dollar Mermaid	1952 (Col)
George Folsey	All the Brothers Were Valiant	1953 (Col)
George Folsey	Executive Suite	1954 (B&W)
George Folsey	Seven Brides for Seven Brothers	1954 (Col)
George Folsey	The Balcony	1963 (B&W)
Robert Fraisse	The Lover	1993
William Fraker	Looking for Mr. Goodbar	1977
William Fraker	Heaven Can Wait	1978
William Fraker	1941	1979
William Fraker	Wargames	1984
William Fraker	Murphey's Romance	1986
FREDDIE FRANCIS	SONS AND LOVERS	1960 (B&W)
FREDDIE FRANCIS	GLORY	1990
Ellsworth Fredericks	Sayonara	1957
KARL FREUND	THE GOOD EARTH	1937
Karl Freund	The Chocolate Soldier	1941 (B&W)
Karl Freund	Blossoms in the Dust	1941 (Col)
Lee Garmes	Morocco	1930/31
LEE GARMES	SHANGHAI EXPRESS	1931/32
Lee Garmes	Since You Went Away	1944 (B&W)
Lee Garmes	The Big Fisherman	1959 (Col)
Gaetano Gaudio	Hell's Angels	1929/30
GAETANO GAUDIO	ANTHONY ADVERSE	1936
Gaetano Gaudio	The Letter	1940 (B&W)
Tony Gaudio	Corvette	1943 (B&W)
Tony Gaudio	A Song to Remember	1945 (Col)
ALFRED GILKS	AN AMERICAN IN PARIS	1951 (Col)
Bert Glennon	Stagecoach	1939 (B&W)
Bert Glennon	Dive Bomber	1941 (Col)
Stephen Goldblatt	The Prince of Tides	1992
GUY GREEN	GREAT EXPECTATIONS	1947 (B&W)
Jack N. Green	Unforgiven	1993
Adam Greenberg	Terminator II: Judgement Day	1992
Howard Greene	Arabian Nights	1942 (Col)
Howard Greene	The Private Lives of Elizabeth and Essex	1939 (Col)
Howard Greene	North West Mounted Police	1940 (Col)

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Howard Greene	Blossoms in the Dust	1941 (Col)
Howard Greene	Jungle Book	1942 (Col)
HOWARD GREENE	PHANTOM OF THE OPERA	1943 (Col)
Howard Greene	When Worlds Collide	1951 (Col)
LOYAL GRIGGS	SHANE	1953 (Col)
Loyal Griggs	The Ten Commandments	1956 (Col)
Loyal Griggs	In Harm's Way	1965 (B&W)
Loyal Griggs	The Greatest Story Ever Told	1965 (Col)
Marcel Grignon	Is Paris Burning	1966 (B&W)
BURNETT GUFFEY	FROM HERE TO ETERNITY	1953 (B&W)
Burnett Guffey	The Harder They Fall	1956 (B&W)
Burnett Guffey	Bird Man of Alcatraz	1962 (B&W)
Burnett Guffey	King Rat	1965 (B&W)
BURNETT GUFFEY	BONNIE & CLYDE	1967
Conrad Hall	Morituri	1965 (B&W)
Conrad Hall	The Professionals	1966 (Col)
Conrad Hall	In Cold Blood	1967
CONRAD HALL	BUTCH CASSIDY AND THE SUNDANCE KID	1969
Conrad Hall	The Day of the Locust	1975
Conrad Hall	Tequila Sunrise	1989
Conrad Hall	Searching for Bobby Fisher	1994
Harry Hallenberg	Louisiana Purchase	1941 (Col)
Ernest Haller	Jezebel	1938
ERNEST HALLER	GONE WITH THE WIND	1939 (Col)
Ernest Haller	All This, And Heaven Too	1940 (B&W)
Ernest Haller	The Flame and the Arrow	1950 (Col)
Ernest Haller	What Ever Happened to Baby Jane?	1962 (B&W)
Ernest Haller	Lilies of the Field	1963 (B&W)
Russell Harlan	The Big Sky	1952 (B&W)
Russell Harlan	Blackboard Jungle	1955 (B&W)
Russell Harlan	To Kill a Mockingbird	1962 (B&W)
Russell Harlan	Hatari!	1962 (Col)
Russell Harlan	The Great Race	1965 (Col)
Russell Harlan	Hawaii	1966 (Col)
Charles Hartan	Butterfield 8	1960 (Col)
Ken Higgins	Georgy Girl	1966 (B&W)
JACK HILDYARD	THE BRIDGE ON THE RIVER KWAI	1957
Sinsaku Himeda	Tora! Tora! Tora!	1970
WINTON HOCH	JOAN OF ARC	1948 (Col)
WINTON HOCH	SHE WORE A YELLOW RIBBON	1949 (Col)
WINTON HOCH	THE QUIET MAN	1952 (Col)
Arthur Ibbetson	Anne Of The Thousand Days	1969
Harry Jackson	Mother Wore Tights	1947 (Col)
Ray June	Arrowsmith	1931/32
Ray June	Barbary Coast	1935
Ray June	Funny Face	1957
JANUSZ KAMINISKI	SCHINDLER'S LIST	1994
BORIS KAUFMAN	ON THE WATERFRONT	1954 (B&W)
Boris Kaufman	Baby Doll	1956 (B&W)
Richard Kline	Camelot	1967
Richard Kline	King Kong	1976
Fred Koenekamp	Patton	1970
FRED KOENEKAMP	THE TOWERING INFERNO	1974
Fred Koenekamp	Island in The Stream	1977
ROBERT KRASKER	THE THIRD MAN	1950 (B&W)
Milton Krasner	Arabian Nights	1942 (Col)
Milton Krasner	All About Eve	1950 (B&W)
MILTON KRASNER	THREE COINS IN THE FOUNTAIN	1954 (Col)
Milton Krasner	An Affair to Remember	1957
Milton Krasner	Love With The Proper Stranger	1963 (B&W)
Milton Krasner	How The West Was Won	1963 (Col)
Milton Krasner	Fate is The Hunter	1964 (B&W)
Charles Lang	The Right to Love	1930/31
CHARLES LANG	A FAREWELL TO ARMS	1932/33
Charles Lang	Arise, My Love	1940 (B&W)
Charles Lang	Sundown	1941 (B&W)
Charles Lang	So Proudly We Hail	1943 (B&W)
Charles Lang	The Uninvited	1944 (B&W)
Charles Lang	The Ghost and Mrs. Muir	1947 (B&W)
Charles Lang	A Foreign Affair	1948 (B&W)
Charles Lang	Sudden Fear	1952 (B&W)
Charles Lang	Sabrina	1954 (B&W)
Charles Lang	Queen Bee	1955 (B&W)
Charles Lang	Separate Tables	1958 (B&W)
Charles Lang	Some Like It Hot	1959 (B&W)
Charles Lang	The Facts of Life	1960 (B&W)
Charles Lang	One-Eyed Jacks	1961 (Col)
Charles Lang	How The West Was Won	1963 (Col)
Charles Lang	Bob & Carol & Ted & Alice	1969
Charles Lang	Butterflies are Free	1972
JOSEPH LA SHELLE	LAURA	1944 (B&W)
Joseph La Shelle	Come to the Stable	1949 (B&W)
Joseph La Shelle	My Cousin Rachel	1952 (B&W)
Joseph La Shelle	Marty	1955 (B&W)
Joseph La Shelle	Career	1959 (B&W)

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Joseph La Shelle	The Apartment	1960 (B&W)
Joseph La Shelle	How The West Was Won	1963 (Col)
Joseph La Shelle	Irma La Douce	1963 (Col)
Joseph La Shelle	The Fotune Cookie	1966 (B&W)
WALTER LASSALLY	ZORBA THE GREEK	1964 (B&W)
Ernest Laszlo	Inherit the Wind	1960 (B&W)
Ernest Laszlo	Judgement at Nuremberg	1961 (B&W)
Ernest Laszlo	It's A Mad, Mad, Mad World	1963 (Col)
ERNEST LASZLO	SHIP OF FOOLS	1965 (B&W)
Ernest Laszlo	Fantastic Voyage	1966 (Col)
Ernest Laszlo	Star	1968
Ernest Laszlo	Airport	1970
Ernest Laszlo	Logan's Run	1976
Philip Lathrop	The Americanization of Emily	1964 (B&W)
Philip Lathrop	Earthquake	1974
SAM LEAVITT	THE DEFIANT ONES	1958 (B&W)
Sam Leavitt	Anatomy of a Murder	1959 (B&W)
Sam Leavitt	Exodus	1960 (Col)
LIONEL LINDON	AROUND THE WORLD IN 80 DAYS	1956 (Col)
Lionel Lindon	I Want to Live!	1958 (B&W)
Lionel Lindon	Going My Way	1944 (B&W)
Harold Lipstein	A Man Called Peter	1955 (Col)
Joseph MacDonald	The Young Lions	1958 (B&W)
Joseph MacDonald	Pepe	1960 (Col)
Joseph MacDonald	The Sand Pebbles	1966 (Col)
Glen MacWilliams	Lifeboat	1944 (B&W)
Peverell Marley	Suez	1938
Peverell Marley	Life with Father	1947 (Col)
Oliver Marsh	Bitter Sweet	1940 (Col)
Charles Marshall	Air Force	1943 (B&W)
Rudolph Mate	Foreign Correspondent	1940 (B&W)
Rudolph Mate	That Hamilton Woman	1941 (B&W)
Rudolph Mate	The Pride of the Yankees	1942 (B&W)
Rudolph Mate	Sahara	1943 (B&W)
Rudolph Mate	Cover Girl	1944 (Col)
Ted McCord	Johnny Belinda	1948 (B&W)
Ted McCord	Two For the Seesaw	1962 (B&W)
Ted McCord	The Sound of Music	1965 (Col)
Barney McGill	Svengali	1930/31
WILLIAM MELLOR	A PLACE IN THE SUN	1951 (B&W)
William Mellor	Peyton Place	1957
WILLIAM MELLOR	THE DIARY OF ANNE FRANK	1959 (B&W)
William Mellor	The Greatest Story Ever Told	1965 (Col)
CHRIS MENGES	THE KILLING FIELDS	1985
CHRIS MENGES	THE MISSION	1987
John Mescall	Take A Letter, Darling	1942 (B&W)
Russell Metty	Flower Drum Song	1961 (Col)
RUSSELL METTY	SPARTACUS	1960 (Col)
Arthur Miller	The Blue Bird	1940 (Col)
ARTHUR MILLER	HOW GREEN WAS MY VALLEY	1941 (B&W)
Arthur Miller	This Above All	1942 (B&W)
ARTHUR MILLER	THE SONG OF BERNADETTE	1943 (B&W)
Arthur Miller	The Keys of the Kingdom	1945 (B&W)
ARTHUR MILLER	ANNA AND THE KING OF SIAM	1946 (B&W)
Ernest Miller	Army Girl	1938
Virgil Miller	Navajo	1952 (B&W)
Victor Milner	The Love Parade	1929/30
VICTOR MILNER	CLEOPATRA	1934
Victor Milner	The Crusades	1935
Victor Milner	The General Died at Dawn	1936
Victor Milner	The Buccaneer	1938
Victor Milner	North West Mounted Police	1940 (Col)
Victor Milner	Reap the Wild Wind	1942 (Col)
Victor Milner	The Furies	1950 (B&W)
HAL MOHR	A MIDSUMMER NIGHT'S DREAM	1935
HAL MOHR	PHANTOM OF THE OPERA	1943 (Col)
Hal Mohr	The Four Poster	1953 (B&W)
TED MOORE	A MAN FOR ALL SEASONS	1966 (Col)
Oswald Morris	Oliver	1968
OSWALD MORRIS	FIDDLER ON THE ROOF	1971
Oswald Morris	The Wiz	1978
Nicholas Musuraca	I Remember Mama	1948 (B&W)
Asakazu Nakai	Ran	1986
SVEN NYKVIST	CRIES AND WHISPERS	1973
SVEN NYKVIST	FANNY AND ALEXANDRA	1983
Sven Nykvist	The Unbearable Lightness of Being	1989
Miroslav Ondricek	Ragtime	1981
Miroslav Ondricek	Amadeus	1985
Ernest Palmer	Four Devils	1928/29
Ernest Palmer	Street Angel	1928/29
ERNEST PALMER	BLOOD AND SAND	1941 (Col)
Ernest Palmer	Broken Arrow	1950 (Col)
GEORGE PERINAL	THIEF OF BAGDAD	1940 (Col)

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Harry Perry	Hell's Angels	1929/30
Don Peterman	Flashdance	1984
Don Peterman	Star Trek IV: The Voyage Home	1987
Frank Phillips	The Black Hole	1979
Tony Pierce-Roberts	A Room With a View	1987
Tony Pierce-Roberts	Howard's End	1993
Robert Planck	Anchors Aweigh	1945 (Col)
Robert Planck	The Three Musketeers	1948 (Col)
Robert Planck	Little Women	1949 (Col)
Robert Planck	Lili	1953 (Col)
Frank Planer	Champion	1949 (B&W)
Frank Planer	Death of a Salesman	1950 (B&W)
Frank Planer	Roman Holiday	1953 (B&W)
Franz Planer	The Nun's Story	1959 (Col)
Franz Planer	The Children's Hour	1961 (B&W)
Sol Polito	The Private Lives of Elizabeth and Essex	1939 (Col)
Sol Polito	Sergeant York	1941 (B&W)
Sol Polito	Captains of the Clouds	1942 (Col)
RAY RENNAHAN	GONE WITH THE WIND	1939 (Col)
RAY RENNAHAN	BLOOD AND SAND	1941 (Col)
Ray Rennahan	Louisiana Purchase	1941 (Col)
Ray Rennahan	For Whom The Bell Tolls	1943 (Col)
Ray Rennahan	Lady in the Dark	1944 (Col)
Ray Rennahan	The Blue Bird	1940 (Col)
Ray Rennahan	Down Argentine Way	1940 (Col)
Robert Richardson	Platoon	1987
Robert Richardson	Born on the 4th of July	1990
ROBERT RICHARDSON	JFK	1992
Owen Roizman	The French Connection	1971
Owen Roizman	The Exorcist	1973
Owen Roizman	Network	1976
Owen Roizman	Tootsie	1982
Charles Rosher	My Best Girl	1927/28
CHARLES ROSHER	SUNRISE	1927/28
Charles Rosher	The Tempest	1927/28
Charles Rosher	The Affairs of Cellini	1934
Charles Rosher	Kismet	1944 (Col)
CHARLES ROSHER	THE YEARLING	1946 (Col)
Charles Rosher	Annie Get Your Gun	1950 (Col)
Charles Rosher	Show Boat	1951 (Col)
Harold Rosson	Boom Town	1940 (B&W)
Harold Rosson	Thirty Seconds over Tokyo	1944 (B&W)
Harold Rosson	The Asphalt Jungle	1950 (B&W)
Harold Rosson	The Bad Seed	1956 (B&W)
Giuseppe Rotunno	All That Jazz	1979
Phillippe Rousselot	Hope and Glory	1988
Phillippe Rousselot	Henry & June	1991
PHILLIPPE ROUSSELOT	A RIVER RUNS THROUGH IT	1993
John Russell	Psycho	1960 (B&W)
JOSEPH RUTTENBERG	THE GREAT WALTZ	1938
Joseph Ruttenberg	Waterloo Bridge	1940 (B&W)
Joseph Ruttenberg	Dr. Jekyll & Mr. Hyde	1941 (B&W)
JOSEPH RUTTENBERG	MRS. MINIVER	1942 (B&W)
Joseph Ruttenberg	Madame Curie	1943 (B&W)
Joseph Ruttenberg	Gaslight	1944 (B&W)
Joseph Ruttenberg	Julius Caesar	1953 (B&W)
JOSEPH RUTTENBERG	SOMEBODY UP THERE LIKES ME	1956 (B&W)
JOSEPH RUTTENBERG	GIGI	1958 (Col)
Joseph Ruttenberg	Butterfield 8	1960 (Col)
Takao Saito	Ran	1986
Masamichi Satch	Tora! Tora! Tora!	1970
Charles Schoenbaum	Little Women	1949 (Col)
John Seale	Witness	1986
John Seale	Rain Man	1989
John Seitz	The Divine Lady	1928/29
John Seitz	Five Graves to Cairo	1943 (B&W)
John Seitz	Double Indemnity	1944 (B&W)
John Seitz	The Lost Weekend	1945 (B&W)
John Seitz	Sunset Boulevard	1950 (B&W)
John Seitz	When Worlds Collide	1951 (Col)
John Seitz	Rogue Cop	1954 (B&W)
DEAN SEMLER	DANCES WITH WOLVES	1991
Leon Shamroy	The Young in Heart	1938
Leon Shamroy	Down Argentine Way	1940 (Col)
Leon Shamroy	Ten Gentlemen from West Point	1942 (B&W)
LEON SHAMROY	THE BLACK SWAN	1942 (Col)
LEON SHAMROY	WILSON	1944 (Col)
LEON SHAMROY	LEAVE HER TO HEAVEN	1945 (Col)
Leon Shamroy	Prince of Foxes	1949 (B&W)
Leon Shamroy	David and Bathsheba	1951 (Col)
Leon Shamroy	The Snows of Kilimanjaro	1952 (Col)
Leon Shamroy	The Robe	1953 (Col)
Leon Shamroy	The Egyptian	1954 (Col)
Leon Shamroy	Love is a Many-Splendored Thing	1955 (Col)
Leon Shamroy	The King & I	1956 (Col)

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Leon Shamroy	South Pacific	1958 (Col)
Leon Shamroy	Porgy and Bess	1959 (Col)
Leon Shamroy	The Cardinal	1963 (Col)
LEON SHAMROY	CLEOPATRA	1963 (Col)
Leon Shamroy	The Agony And The Ecstasy	1965 (Col)
EUGEN SHUFTAN	THE HUSTLER	1961 (B&W)
William Skall	Northwest Passage	1940 (Col)
William Skall	Billy the Kid	1941 (Col)
William Skall	Arabian Nights	1942 (Col)
William Skall	Reap the Wild Wind	1942 (Col)
William Skall	To The Shores of Tripoli	1942 (Col)
William Skall	Life with Father	1947 (Col)
WILLIAM SKALL	JOAN OF ARC	1948 (Col)
William Skall	Quo Vadis	1951 (Col)
William Skall	The Silver Chalice	1954 (Col)
Douglas Slocombe	Travels With My Aunt	1972
Douglas Slocombe	Julia	1977
Douglas Slocombe	Raiders of the Lost Ark	1981
Leonard Smith	Billy the Kid	1941 (Col)
Leonard Smith	Lassie Come Home	1943 (Col)
Leonard Smith	National Velvet	1945 (Col)
LEONARD SMITH	THE YEARLING	1946 (Col)
William Snyder	The Loves of Carmen	1948 (Col)
William Snyder	Jolson Sings Again	1949 (Col)
Mikael Solomon	The Abyss	1990
Harold Stine	The Poseidon Adventure	1972
VITTORIO STORARO	APOCALYPSE NOW	1979
VITTORIO STORARO	REDS	1981
VITTORIO STORARO	THE LAST EMPEROR	1988
Vittorio Storaro	Dick Tracy	1991
ARCHIE STOUT	THE QUIET MAN	1952 (Col)
Harry Stradling	The Human Comedy	1943 (B&W)
HARRY STRADLING	THE PICTURE OF DORIAN GREY	1945 (B&W)
Harry Stradling	The Barkleys of Broadway	1949 (Col)
Harry Stradling	A Streetcar Named Desire	1951 (B&W)
Harry Stradling	Hans Christian Anderson	1952 (Col)
Harry Stradling	Guys and Dolls	1955 (Col)
Harry Stradling	The Eddy Duchin Story	1956 (Col)
Harry Stradling	Auntie Mame	1958 (Col)
Harry Stradling	The Young Philadephians	1959 (B&W)
Harry Stradling	A Majority of One	1961 (Col)
Harry Stradling	Gypsy	1962 (Col)
HARRY STRADLING	MY FAIR LADY	1964 (Col)
Harry Stradling	Funny Girl	1968
Harry Stradling	Hello, Dolly!	1969
Harry Stradling	1776	1972
Harry Stradling	The Way We Were	1973
Walter Strenge	Stagecoach to Fury	1956 (B&W)
Karl Struss	Drums of Love	1927/28
KARL STRUSS	SUNRISE	1927/28
Karl Struss	Dr. Jekyil & Mr. Hyde	1930/32
Karl Struss	Sign of the Cross	1932/33
Karl Struss	Aloma of the South Seas	1941 (Col)
Bruce Surtees	Lenny	1974
Robert Surtees	Thirty Seconds over Tokyo	1944 (B&W)
ROBERT SURTEES	KING SOLOMON'S MINES	1950 (Col)
Robert Surtees	Quo Vadis	1951 (Col)
ROBERT SURTEES	THE BAD & THE BEAUTIFUL	1952 (B&W)
Robert Surtees	Oklahoma!	1955 (Col)
ROBERT SURTEES	BEN-HUR	1959 (Col)
Robert Surtees	Mutiny On The Bounty	1962 (Col)
Robert Surtees	Doctor Dolittle	1967
Robert Surtees	The Graduate	1967
Robert Surtees	The Last Picture Show	1971
Robert Surtees	Summer of '42	1971
Robert Surtees	The Sting	1973
Robert Surtees	The Hindenberg	1975
Robert Surtees	A Star Is Born	1976
Robert Surtees	The Turning Point	1977
Robert Surtees	Same Time Next Year	1978
RONNIE TAYLOR	GANDHI	1982
Ted Tetzlaff	The Talk of the Town	1942 (B&W)
Alex Thompson	Excalibur	1981
Gregg Toland	Les Miserables	1935
Gregg Toland	Dead End	1937
GREGG TOLAND	WUTHERING HEIGHTS	1939 (B&W)
Gregg Toland	The Long Voyage Home	1940 (B&W)
Gregg Toland	Citizen Kane	1941 (B&W)
Leo Tover	Hold Back the Dawn	1941 (B&W)
Leo Tover	The Heiress	1949 (B&W)
Masaharu Ueda	Ran	1986
Geoffrey Unsworth	Becket	1964 (Col)
GEOFFREY UNSWORTH	CABARET	1972

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Geoffrey Unsworth	Murder on the Orient Express	1974
GEOFFREY UNSWORTH	TESS	1980
Jost Vacano	Das Boot	1982
Joseph Valentine	Wings Over Honolulu	1937
Joseph Valentine	Mad About Music	1938
Joseph Valentine	Spring Parade	1940 (B&W)
JOSEPH VALENTINE	JOAN OF ARC	1948 (Col)
WILLARD VAN DE VEER	WITH BYRD AT THE SOUTH POLE	1929/30
PAUL VOGEL	BATTLEGROUND	1949 (B&W)
Paul Vogel	The Wonderful World of the Brothers Grimm	1962 (Col)
Sidney Wagner	Northwest Passage	1940 (Col)
JOSEPH WALKER	WITH BYRD AT THE SOUTH POLE	1929/30
Sidney Wagner	Dragon Seed	1944 (B&W)
Joseph Walker	You Can't Take It With You	1938
Joseph Walker	Here Comes Mr. Jordan	1941 (B&W)
Joseph Walker	The Jolson Story	1946 (Col)
John Warren	The Country Girl	1954 (B&W)
DAVID WATKIN	OUT OF AFRICA	1986
HASKELL WEXLER	WHO'S AFRAID OF VIRGINIA WOOLF?	1966 (B&W)
Haskell Wexler	One Flew Over the Cuckoo's Nest	1975
HASKELL WEXLER	BOUND FOR GLORY	1976
Heskell Wexler	Matewan	1988
Heskell Wexler	Blaze	1990
Harry Wild	Army Girl	1938
Billy Williams	Women in Love	1970
Billy Williams	On Golden Pond	1981
BILLY WILLIAMS	GANDHI	1982
Gordon Willis	Zelig	1984
Gordon Willis	The Godfather, Part III	1991
James Wong Howe	Algiers	1938
James Wong Howe	Abe Lincoln In Illinois	1940 (B&W)
James Wong Howe	Kings Row	1942 (B&W)
James Wong Howe	Air Force	1943 (B&W)
James Wong Howe	The North Star	1943 (B&W)
JAMES WONG HOWE	THE ROSE TATTOO	1955 (B&W)
James Wong Howe	The Old Man and The Sea	1958 (Col)
JAMES WONG HOWE	HUD	1963 (B&W)
James Wong Howe	Seconds	1966 (B&W)
James Wong Howe	Funny Lady	1975
WALTER WOTTITZ	THE LONGEST DAY	1962 (B&W)
Freddie Young	Ivanhoe	1952 (Col)
FREDDIE YOUNG	LAWRENCE OF ARABIA	1962 (Col)
FREDDIE YOUNG	DOCTOR ZHIVAGO	1965 (Col)
FREDDIE YOUNG	RYAN'S DAUGHTER	1970
Freddie Young	Nicholas and Alexandra	1971
VILMOS ZSIGMOND	CLOSE ENCOUNTERS OF THE THIRD KIND	1977
Vilmos Zsigmond	The Deer Hunter	1978
Vilmos Zsigmond	The River	1985

3 BATTERIES

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Two distinctly different types of rechargeable batteries are used to power portable film and television cameras, SEALED NICKEL CADMIUM and SEALED LEAD ACID.

Sealed nickel cadmium batteries have a nominal voltage of 1.2v per cell and require constant current charging. Sealed lead acid batteries, on the other hand, have a nominal voltage of 2v per cell and are generally charged from a constant voltage source.

Neither the cells nor the chargers are interchangeable, one with the other.

The capacity of a battery is described in 'amp-hours'. In theory a 1Ah battery should be able to produce 1 amp of power for one hour and a 4Ah cell 4 amps for one hour, regardless of the voltage.

Increased voltage is achieved by wiring up a number of cells in series.

The charging rate of a cell or battery is described as *C/x*, i.e. the capacity of the cell divided by the amperage of the charging current.

3.1 SEALED NICKEL CADMIUM CELLS

One of the most frequently used types of rechargeable power supplies for cameras and other portable equipment is the sintered plate nickel cadmium multi-cell battery. Properly used and maintained they are clean, reliable, have a good power to weight ratio and are good value for money.

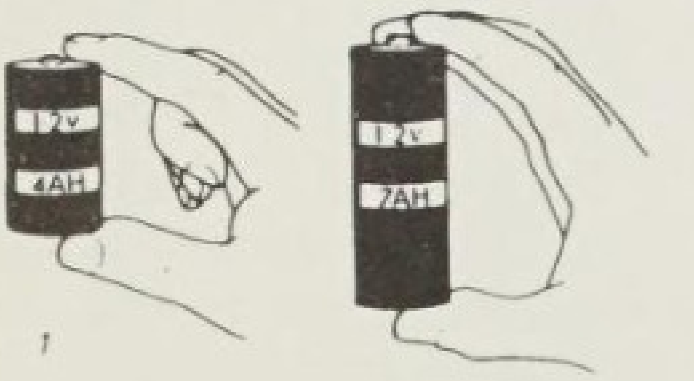
Sealed nickel cadmium cells are rechargeable, have a nominal voltage of 1.2v per cell, are maintenance free, non-gassing and may be connected together in series to make up batteries of higher voltage. Nickel cadmium cells are available in button form (small capacities from 10mAh to 1Ah), cylindrical form (500mAh to 10Ah) and rectangular form (1.6Ah to 15Ah).

Irrespective of whether they are button, cylindrical or rectangular, nickel cadmium cells have positive and negative electrodes made of nickel oxyhydroxide and cadmium metal, respectively, separated by a highly porous separator which absorbs a dilute potassium hydroxide electrolyte.

Nickel cadmium cells may be of the 'mass plate' or 'sintered plate' type. It should be noted that the bodies of many cells are not insulated and must be insulated from each other when made up into batteries.

The bodies of mass plate nickel cadmium cells of the button and cylindrical cell types may be stacked end to end to form a cylindrical battery.

For use in cinematographic and television equipment stacked button cell batteries are sometimes used where high voltage, low capacity batteries are required. Cylindrical cells are usually used for camera batteries and rectangular cells often to power battery portable lights.



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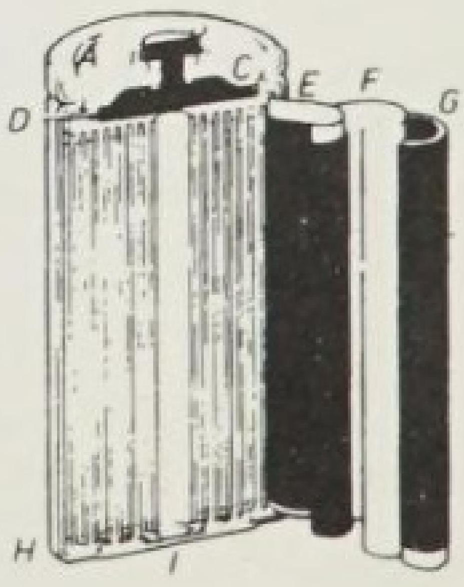

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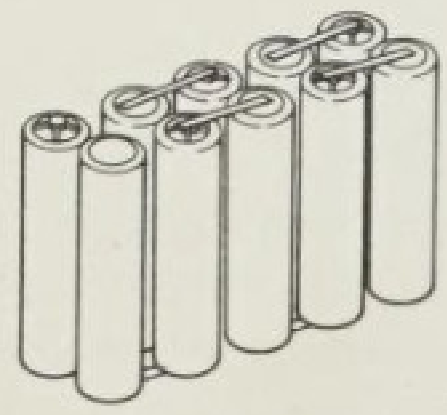

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NICKEL CADMIUM CELLS: 1. 1.2v Nickel cadmium cells of different capacity; 2. Construction of a typical nickel cadmium battery cell: A. Cover; B. Central button (Positive pole); C. Safety vent; D. Positive connections; E. Positive plate; F. Separator; G. Negative plate; H. Nickel-plated steel case; I. Negative connections; 3. Arrangement of cells for a 12v battery and pin connections for XLR canon plugs.

3.1.1 Nickel cadmium cell characteristics

The 'rated' capacity of nickel cadmium batteries is that which may be obtained when fully charged 1.2v cells are discharged to 1.0v per cell at a rate equal to one-fifth the rated capacity (C/5 Amps). Thus a fully charged battery of 7Ah capacity should, in theory, give a life of 5 hours when discharged at a constant current of 1.4A to 1.0v per cell at –20°C. Higher rate discharge rates will give a lower returned capacity.

Cell performance is also influenced by variations in the manner in which it is charged, on variations in the discharge rate (depth of discharge), the storage temperature (after charging and during discharge) and previous cell history.

During the early life of a nickel cadmium cell there is a slight cycle loss of capacity but after some 10–12 cycles the capacity stabilizes and remains constant for a considerable period. The loss of capacity during the first few cycles is dependent on discharge rate, increasing with higher discharge rates. The capacities quoted by cell manufacturers are usually obtained after this initial loss of capacity has been completed. If the discharge rate is suddenly increased or decreased the cell will respond within a few cycles and then give a capacity compatible with its new discharge rate.

The voltage of the nickel cadmium cell remains virtually constant at 1.2v per cell until discharge is almost complete, when it drops rapidly. This is true for all discharge rates and is the reason that the state of charge of a nickel cadmium cell cannot be measured by the simple expedient of taking a voltage reading. The only meaningful way is to time the discharge at a known rate to a base voltage of 1 volt per cell.

1. Maximum duration of discharge that may be expected of a fully charged nickel cadmium battery in good condition at 20°C (68°F).

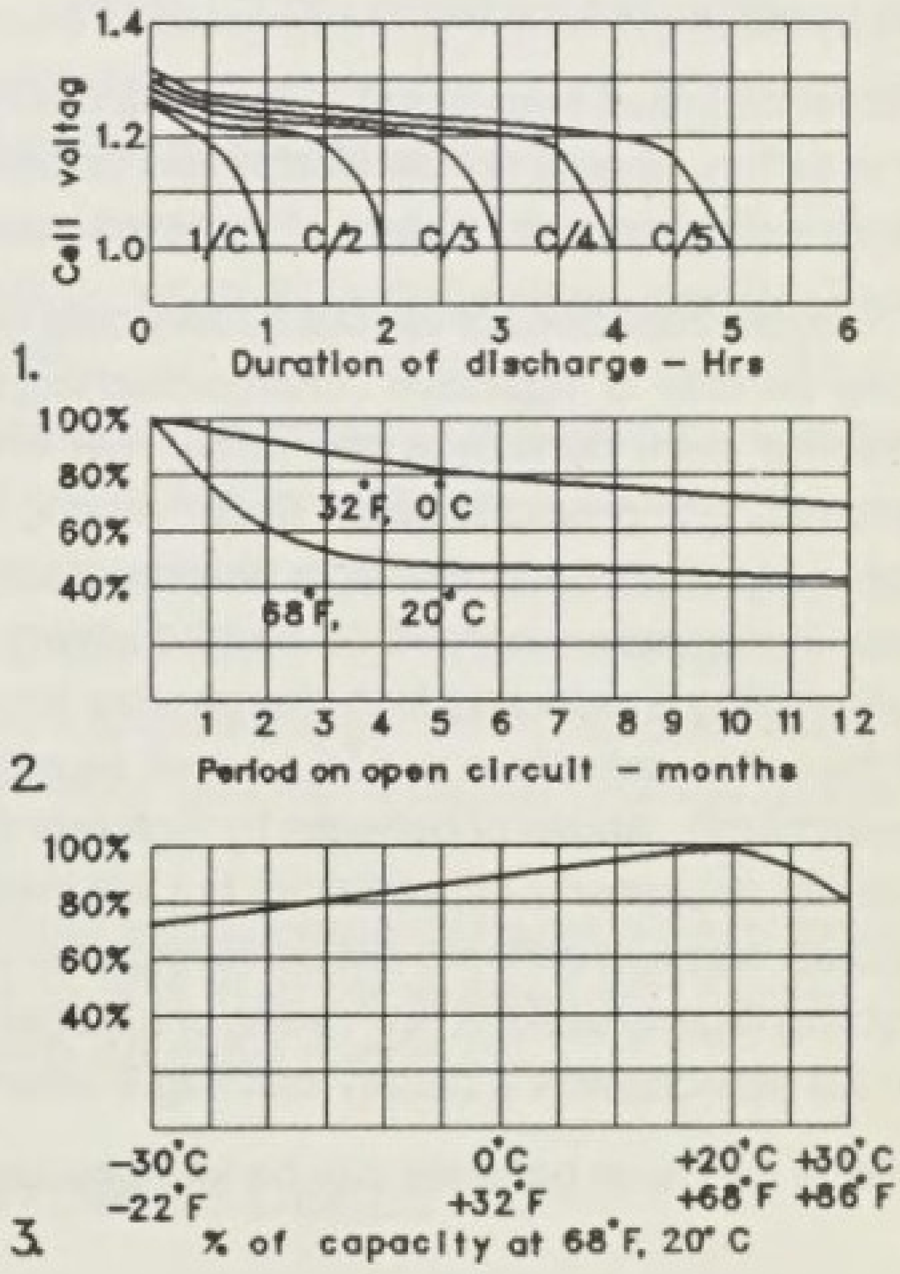
1/C = a discharge rate equal to the capacity of the cell.

Note how the voltage remains constant until a given point when it drops sharply.

2. Self discharge of a nickel cadmium battery stored in cold and warm conditions. Note how a cell stored in cold conditions will retain a charge longer than when warm.

A number of cells connected in series as a battery will discharge more rapidly than a single cell.

3. Comparative efficiency of nickel cadmium cells at various temperatures. Note how the battery is least efficient when very cold and reaches at peak of efficiency at 20°C (68°F).



NICKEL CADMIUM BATTERY CHARACTERISTICS: 1. Cell voltage v discharge time;
2. Capacity v open circuit discharge;
3. Capacity v temperature.

3.1.2 Nickel cadmium memory effect

When a nickel cadmium cell is repeatedly discharged only slightly (or not at all) before recharging fully as though it had been deeply discharged it will temporarily lose its ability to deliver its rated capacity. This is erroneously known as the 'memory effect' whereby the cell becomes conditioned by continual shallow discharge, into giving a particular capacity so that when required to return its full capacity it is unable to do so. This effect can be removed and the battery restored to its full capacity by fully recharging and then fully discharging to 1 volt per cell several times in succession. The effect can be avoided by fully discharging on each cycle or by varying the depth of discharge from time to time during the life of the cell.

To minimize memory effect it is most important that batteries are made up of cells of exactly similar characteristics. To make this possible manufacturers grade cells according to their capacity and mark them with color codes (white is the highest rating, red the least). New batteries should not be made up of mixed color coded cells.

3.1.3 Nickel cadmium cell discharge conditions

Nickel cadmium cells give their maximum capacity when discharged at +30°C to +35°C (86° to 95°F) after being charged at +20°C (68°F). At lower discharge temperatures the available capacity becomes less and less until at -30°C (–22°F) it is approximately halved. Nickel cadmium cells can be discharged from –30°C to +50°C, the lower limit being determined by the freezing point of the electrolyte, the upper to prevent possible damage to cell components caused by overheating. The decrease in capacity at either extreme of temperature is greater the higher the discharge rate.

When a nickel cadmium cell is stored for an appreciable time between charge and discharge the storage temperature is a very important consideration.

Fully charged nickel cadmium cells gradually lose capacity whilst stored even when no load is applied. This is known as 'self discharge'. The rate of capacity loss is minimal at 0°C but increases as the temperature rises. At +20°C (68°F) the expected loss is 30% in one month and at +35°C (95°F) loss of capacity would typically be 60% over the same period. It is therefore important to store nickel cadmium batteries in as low a temperature as possible - but not below –30°C (–22°F).

Nickel cadmium batteries should not be discharged below 1.0 volts per cell (a 10-cell 12 volt battery should not be discharged below 10 volts to avoid the possibility of one or more cells going into a state of reversed polarity.

The cyclic capacities of various battery cells quoted by manufacturers are measured over long periods of repetitive charge/discharge under closely controlled conditions. In practice such conditions are rarely met and thus allowances must be made when attempting to predict capacity under varying operating conditions. The 'memory effect', referred to in connection with shallow discharge, can also occur if the batteries are repeatedly under-charged or charged in very hot conditions. The effect of capacity loss with cycling is reduced if high charge rates are used. Lost battery capacity can be regained if the cell is rested for a period, and will be reduced in conditions approaching continuous overcharge. Abuse of batteries by high rate overcharge, reverse charge or short circuits will not necessarily cause failure but will inevitably reduce cell performance and life. If nickel cadmium cells are not achieving their expected performance it may be due to the cycling regime used. A few cycles of full charge followed by deep discharge can restore to full serviceability a battery that might otherwise be rejected.

Nickel cadmium batteries can be killed by kindness.

3.1.4 Charging nickel cadmium batteries

It is recommended that nickel cadmium batteries be recharged at a constant current or that the current be limited to a known value. The use of constant voltage charging systems is not advised due to the possibility of drawing very large currents, with consequent internal overheating and the possible thermal runaway of the cells.

Nickel cadmium cells should be charged in series. Parallel charging is not recommended as small differences in cell voltage can lead to unequal sharing of current.

The voltage of a nickel cadmium battery on charge at room temperature will quickly rise to 1.4 - 1.5 volts per cell.

The cell temperature range for normal charging is +10°C (50°F) to +45°C (115°F) but optimum performance is obtained at +20°C.

At the higher temperatures ample ventilation should be provided to limit the cell temperature to a maximum of +55°C (130°F).

Nickel cadmium batteries which have been fully discharged to 1 volt per cell can safely be recharged at a very high rate for a comparatively short period of time, the maximum rate and time depending upon the cell capacity and type. Unless using a proprietary fast charging system, which has been designed and manufactured in co-operation with the cell manufacturer, users should consult the manufacturers' data sheets and take precautions to avoid over overcharging causing the cells to overheat to the point when they become dangerous.

At room temperature using normal charging conditions the cell voltage increases from a nominal 1.2 volts to an end of charge voltage of approximately 1.45 volts. After charging they should be rested for a period of one or two hours to allow the voltage level to stabilize. This is particularly important if using the battery to power equipment such as battery portable lights and sensitive electronic circuits which are prone to severe damage if connected to too high a voltage.

3.1.5 Vented nickel cadmium Alkaline cells

Vented nickel cadmium Alkaline cells are rectangular in shape and are somewhat larger than the more familiar cylindrical or rectangular plate nickel cadmium cells. They have higher nominal capacities and may be subjected to higher discharge rates and faster recharge cycles than the small types, making them ideal for use with camera motors which draw a heavy current.

Vented cells have a nominal voltage of 1.2v per cell. The nominal capacity of a particular cell can usually be ascertained from the code number stamped on each cell although different manufacturers may quote a different discharge rate, thus a '*xx*' 15 cell will be 15 Ah but at either a C/1 or a C/5 rate, depending on the manufacturer.

Like sintered plate cells, vented cells maintain an almost constant voltage on discharge until they near the end of their useful capacity, when the voltage drops rapidly. They should not be discharged below 1 volt per cell.

When fully charged a vented cell will hold its charge in warm storage conditions somewhat better than a sintered plate cell, but will still self discharge unless kept cool.

As with any other battery power should not be drawn off a part of a multi-cell battery as this will upset the cell balance and adversely affect future battery performance.

Vented cells may be recharged rapidly using a special charger which has built-in safety circuits. Failing such a charger they may be recharged with a constant voltage charger at a rate of 1.40 – 1.45v per cell.

A certain amount of the electrolyte of a vented cell will be consumed if a cell is overcharged (1 cc per 3 Ah overcharge) and from time to time must be replaced with distilled or demineralized water using a syringe fitted with a suitable nozzle.

3.2 NICKEL HYDRIDE CELLS

Nickel Hydride, or NiH_2 cells are said to be less susceptible to 'memory effect' and last up to twice as long as nickel cadmium batteries on a single charge. Also claimed for them are that they are leak-proof so that they do not dry out, that they can endure 500 charge/discharge cycles, that they provide 20% more energy for a given weight than nickel cadmium cells, that they can be recharged without first being fully discharged, that recharging takes only 1.5 hours and that in the unlikely event that they suffer from 'memory effect' they can be restored by a couple of discharges and full recharges. They are also more expensive than nickel cadmium cells.

Nickel Hydride cells have been developed for the portable computer market but no doubt will be available for use with cine cameras before too long.

3.3 SEALED LEAD ACID CELLS

3.3.1 Wound Electrode Lead Acid cells

Sealed lead-acid battery cells designed for higher rate discharges have a wound electrode structure similar to that of nickel cadmium cells but with plates manufactured of pure lead and a separator made of a special glass fibre material. The sulfuric acid electrolyte is held by its own surface tension in the vast surface area of the fine glass fibres. They have all the convenience values of nickel cadmium batteries plus the economy of lead acid.

From the user's point of view the principal difference between sealed lead acid cells and nickel cadmium is that the former are 2+v per cell compared with 1.2 for nickel cadmium.

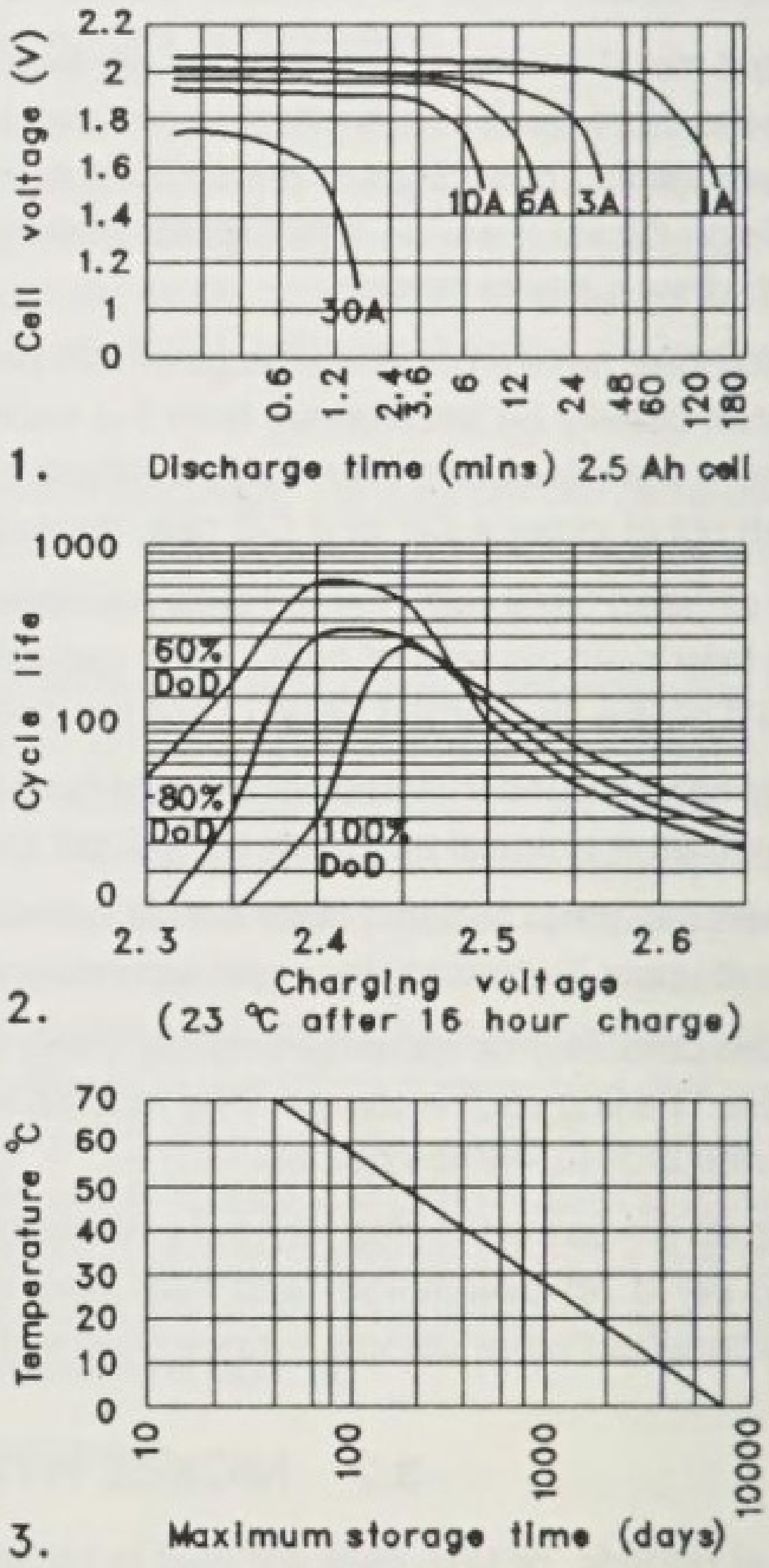
Unlike a 'motor-car' type lead acid accumulator, the sulfuric acid electrolyte of an SLA cell cannot be accidently spilled or be lost due to over-charging and battery 'topping up' is neither necessary nor possible.

Unlike nickel cadmium cells, SLA cells do not suffer from the 'memory effect' of constant shallow discharge. Furthermore, low depths of discharge increase the number of charge/discharge cycles to be expected from the life of a particular battery.

Like the nickel cadmium cell, the voltage of an SLA cell remains fairly constant on discharge until it nears the end of its charge capacity when it falls rapidly and for this reason the state of charge of a recently charged SLA battery cannot be measured with a simple voltmeter. Like the nickel cadmium, the surest way to check the efficiency of an SLA battery is to time its discharge to a base voltage, 1.6v per cell in the case of an SLA, against a known load. When an SLA battery has stood for five days after charging its state of charge may then be checked by a voltmeter across an open circuit (no load on) according to the graph supplied by the manufacturers.

SLA cells self discharge themselves when stored in warm ambient conditions although not as rapidly as nickel cadmium cells and should be kept cool when not in use.

The manufacturers claim that SLA batteries will last for over 700 charge/discharge cycles when charged at a slow charging rate and discharged to not more than 60% of their capacity but only 200 cycles when they are charged rapidly and discharged fully.



SEALED LEAD ACID CELL CHARACTERISTICS: 1. Cell voltage v discharge time; 2. Cycle life v charging voltage and Depth of Discharge (DoD); 3. Storage temperature v storage life.

Typical SLA cells are the Gates Energy Products Cyclon range:

Rated Capacity	Nominal Voltage	Overall Dimensions				Weight	
10hr rate		Diameter		Height			
Ah	v	in	mm	in	mm	oz	gr
2.5	2	1.35	34.2	2.66	67.6	6.4	181
5.0	2	1.75	44.4	3.17	80.6	13.0	369
25.0	2	2.59	65.7	6.95	176.5	56.0	1670

3.3.2 Charging Sealed Lead Acid cells

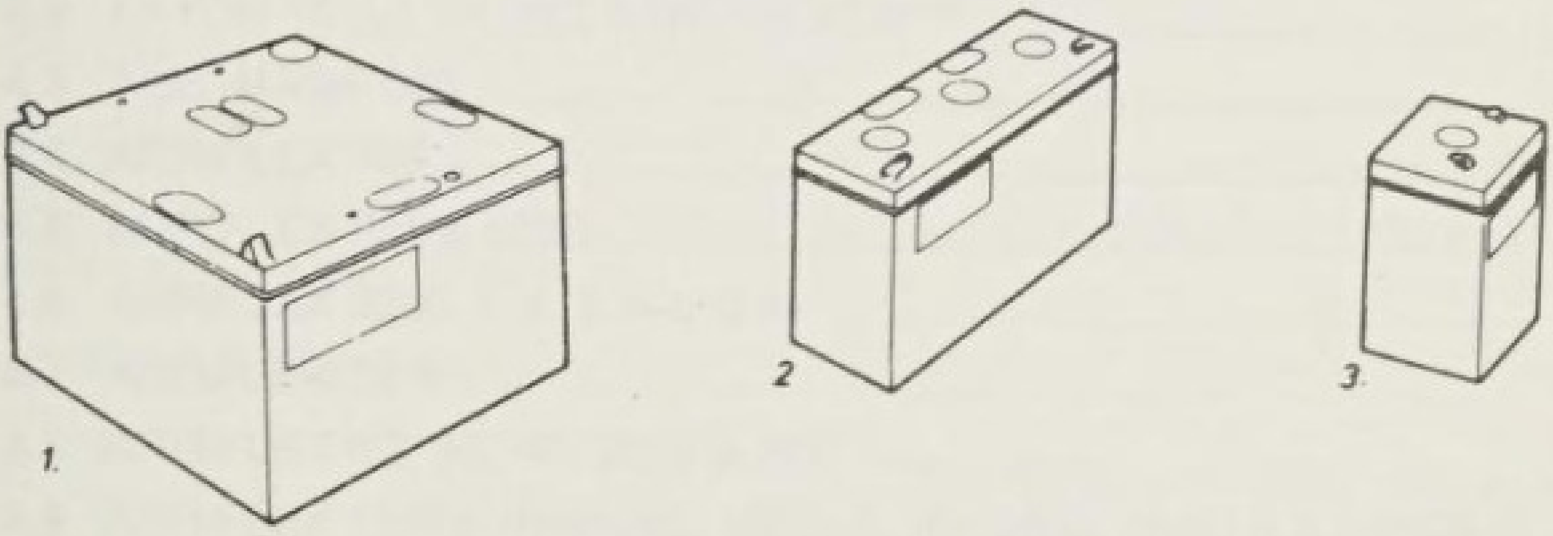
SLA cells should be recharged at a constant voltage of 2.30 – 2.5 volts per cell. At 2.45 volts a fully discharged cell will recharge in 16 hours and have a life expectancy of 200 – 250 charge/discharge cycles. The lower the charging rate the greater the life expectancy of the cells.

SLA cells may also be recharged in 14 – 16 hours using a two-step constant current charger starting at *C*/10 and switching at 2.57 volts per cell to a constant current of *C*/500 or below or to a constant charge voltage of 2.35 volts per cell.

Taper chargers of the inexpensive type bought for recharging car batteries and simple constant current charges should not be used with SLA cells as serious and permanent damage to the life expectancy will be caused if the cells receive an excessive overcharge for a long period of time.

3.3.3 Jelly Lead Acid batteries

Lead acid batteries having jelly electrolyte are usually used where low original cost but comparatively limited cycle life is desirable. They are usually made up into nominal 6 and 12 volt blocks.



JELLY LEAD ACID BATTERY BLOCKS: 1. 12v 20Ah; 2. 6v 7.5Ah; 3. 2v 7.5Ah.

Typical jelly battery cells have an open circuit voltage of 2.10 – 2.20 volts per cell and a nominal 2 volts per cell on load to a cut-off voltage of 1.75v.

Like other batteries, taking an open circuit voltage reading of a recently recharged battery is an unreliable and meaningless indication of the state of charge.

The typical life expectancy of a jelly acid battery is 100 charge/recharge cycles. This compares with a life expectancy of 250 cycles for a sintered plate (wound) lead acid cell and 500+ cycles for a sintered plate nickel cadmium. The higher the discharge rate (C/5 and above) the greater the life expectancy.

Jelly lead acid batteries give of their greatest capacity when warm, are comparatively inefficient when cold. For maximum life they should be stored in a fully charged condition and kept cool to minimize self discharge.

3.4 LITHIUM BATTERIES

Lithium cells of various types are high energy primary cells used in conditions where efficient, compact lightweight cells, which may be used over a long period of time and at extremes of high and low temperature, are a primary requirement. They cannot be recharged and must be disposed of after use.

The voltage of various makes of lithium batteries ranges from 1.5 – 3.5v per cell, the capacities from 0.4 – 30Ah and the temperature ranges in which they may be stored and operated may be as low as –55°C (–67°F) or as high as +70°C (158°F).

The voltage on discharge remains quite flat until it nears the end of its useful life, when it drops sharply.

A typical range made by National are 2.8v per cell, 750, 1200 and 5000m Ah and operate in a temperature range of –20°C to +50°C (–4°F to +122°F).

The recommended standard discharge current is approximately *C*/35 and the maximum continuous discharge current *C*/17.5.

4 CAMERA CHOICE

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The following section is intended as a quick guide to the salient features of most of the cameras currently used for professional motion picture cinematography in the world today. For brevity 'families' of cameras are grouped together although there may be very significant differences between the earliest and the latest versions of a particular basic design.

The mechanisms of high quality film cameras have a remarkable longevity. It is no exaggeration to say that throughout the world there are many cameras in daily use that are fifty and more years old, still taking pictures the image steadiness and quality of which are as high as ever they were. For this reason the following listing includes many cameras which by big feature film standards are obsolescent, or even obsolete, but which, assuredly, are still in use in film schools or elsewhere in the world. Not too long ago the author saw a pre-1920 camera still in use at the Disney studio in Hollywood.

The listing gives only the barest of essential details necessary to distinguish one camera from another and is not in any way intended as an evaluation. It assumes the following:

Movements do not have registration (pilot) pins unless stated.

Shutters of reflex cameras are combined light shutters and rotating mirrors unless otherwise stated.

'Adjustable' shutters are shutters the opening of which can be changed while the camera is stationary and in some cases only with the lens removed.

'Variable' shutters are shutters the opening of which can be changed while the camera is running for in-shot exposure and HMI flicker control, etc.

Viewfinders all have ocular adjustment.

Lens mountings are single ports unless otherwise stated. Motors are standard unless otherwise stated.

Film loading is emulsion-in on 2 inch cores unless otherwise stated.

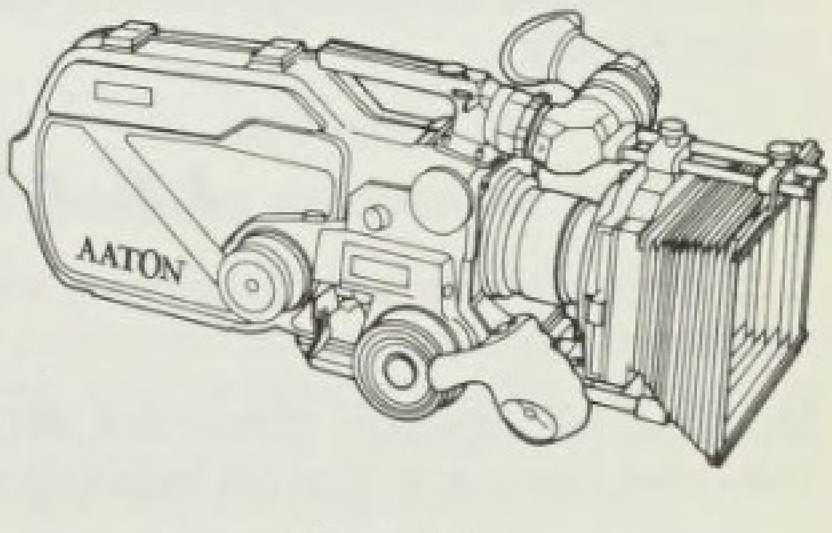
New or prototype cameras are not listed until they have been in use in the industry for a reasonable period of time or unless the manufacturers have committed themselves to produce a significant number for worldwide distribution. Cameras which are marketed or used only in one part of the world also are not included.

4.1 AÄTON 35

A wide film version of the Aäton 16 with added features.

MOVEMENT: Aäton claim that the 'low inertia drive mechanism with a patented coplanar claw movement combined with a lateral pressure plate provides total film steadiness and sharper pictures.'

FORMAT: Lens may easily be re-centered for Super 35 operation and film gate adjusted to suit any screen ratio. A ThreePerf pull-down movement is an available option.



AÄTON 35

SHUTTER: 180° is standard. 172.8° for shooting at 24fps with HMI lighting in 50Hz areas is available on request.

VIEWFINDER: Spinning mirror reflex. Viewfinder is removable for lightweight use. An extension eyepiece with leveller available for tripod use.

LENS MOUNTING: Unique Aäton tilted mirror-shutter and interchangeable lens mounts enable any make of 35mm cine and any 35mm stills camera lenses used.

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 12v motor and the camera electronics combined draw only 2amps. An on-board 4Ah battery will run approx. 24 × 400' magazines. Crystal controlled 2 – 36 fps (including 24, 25, 29.97 & 30 fps). Power transmitted to the magazine take-up drive by magnetic couplings.

FILM LOADING: Unique travelling displacement type 400ft magazines which incorporate the film pressure plate and own electronic footage counter.

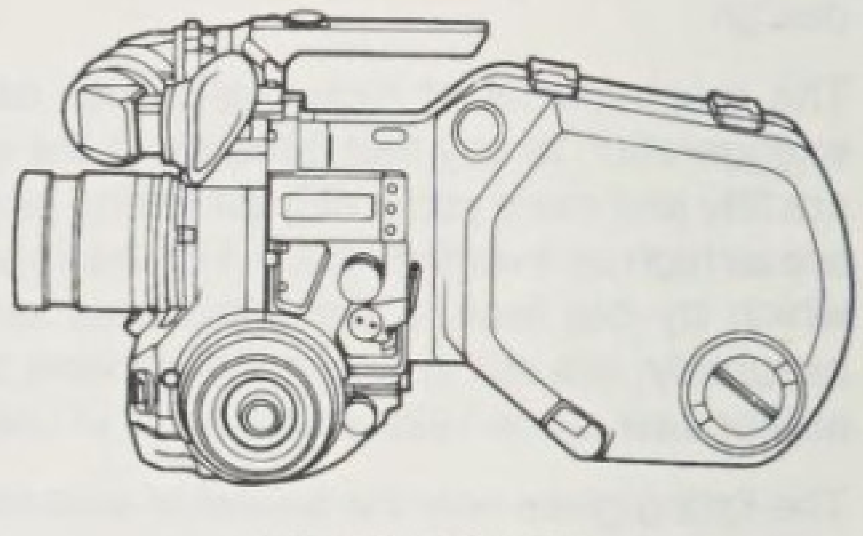
ADDITIONAL FEATURES: Integrated b&w or color CCD video assist, electronic footage remaining display. Weight approx. 15lbs (7 kg) with 400' of film and on-board battery.

AVAILABLE ACCESSORIES: AätonCode time code, lithium battery.

4.2 AÄTON 16 7, LTR, XO, XTR^{plus} & XTR^{prod}

Probably the most comfortable hand-holding camera ever produced. The XTR^{plus} and the XTR^{prod} are the latest and most sophisticated versions.

MOVEMENT: Unique Aäton movement combines a single pull-down claw with edge guidance which is claimed to give exceptional image crispness and an absence of horizontal weaving. An image steadiness of 1/2000" is claimed. Other claims are the elimination of hairs in the gate and a simple system to adjust the aperture to any aspect ratio.


AÄTON XTR^{plus}

SHUTTER: 180° is standard. 172.8° for shooting at 24fps with HMI lighting in 50Hz areas is available on request. XTR^{prod} has a 144/172.8/180° multi-position shutter.

VIEWFINDER: Spinning mirror reflex. Bright fiber optic viewing screen. Left eye and eyepiece extensions are optional. XTR^{prod} has an interchangable ground glass and an illuminated viewing system.

LENS MOUNTING: Unique Aaton BNCR type bayonet mount is standard, Arri PL, Mitchell BNCR & PV mounts are available as are adaptors for Arri B, Eclair CA, Nikon & LeicaR.

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 12v motor. Earlier models have 24/25/30 fps sync speeds (29.97 optional), 6/12/16/18/20/40 fps (54 fps with a 16v battery) with incremental variable speeds. Later models have 2-75 fps speed range, XTR^{prod} has a 0.001 fps incremental setting capability. Cameras draw 60ma with film.

FILM LOADING: Co-axial 400ft magazines which incorporate the film pressure plate and own electronic footage counter. The magazines of the XTR models have magnetic drive couplings and are not interchangeable with the earlier types which have a mechanical system.

ADDITIONAL FEATURES: Easy conversion to Super 16 lens centering, on-board battery, TTL light metering, integrated CCD video assist, pre-end and end of film warning.

AVAILABLE ACCESSORIES: AätonCode time code generator (later models only) to register human-readable information and a Keylink time code reader for telecine machines to automatically synchronize film and tape on transfer. Integral b&w or color video assist, lithium battery.

4.3 AGE IMAGE 300

A 300 fps camera with a spinning mirror reflex system.

MOVEMENT: Epicyclic movement with six pull-down claws and dual pin registration.

SHUTTER: 120° reflex mirror shutter

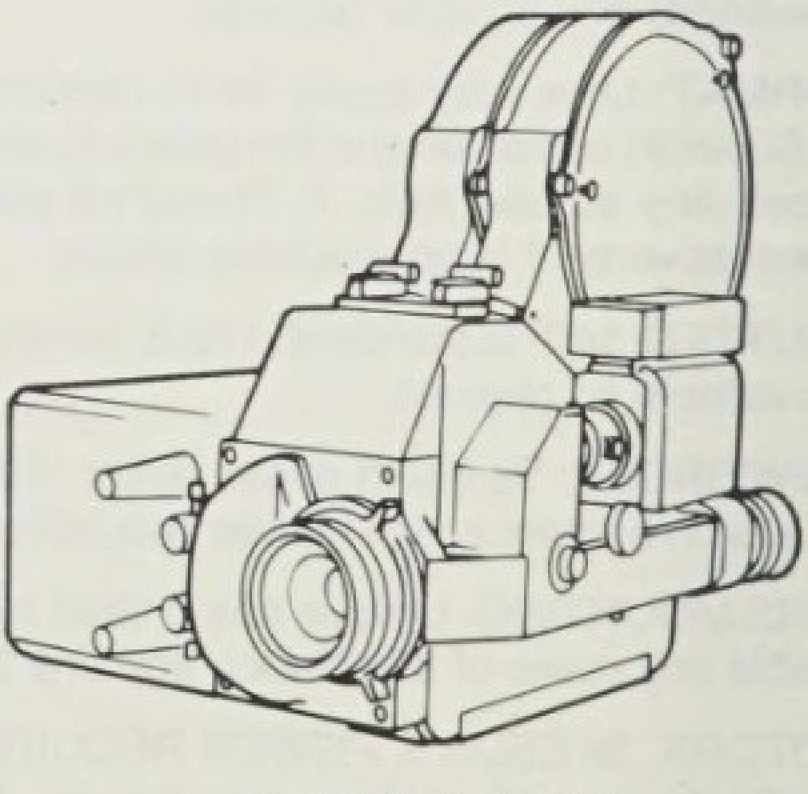
VIEWFINDER: Reflex rotating mirror

LENS MOUNTING: BNCR

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 115v AC 50/60 Hz, 24 - 300 fps.

FILM LOADING: 100 ft co-axial magazines.

ADDITIONAL FEATURES: Strobe light synchronizing outlet.


AGE IMAGE 300

AVAILABLE ACCESSORIES: Video assist, 360° orientatable viewfinder extension.

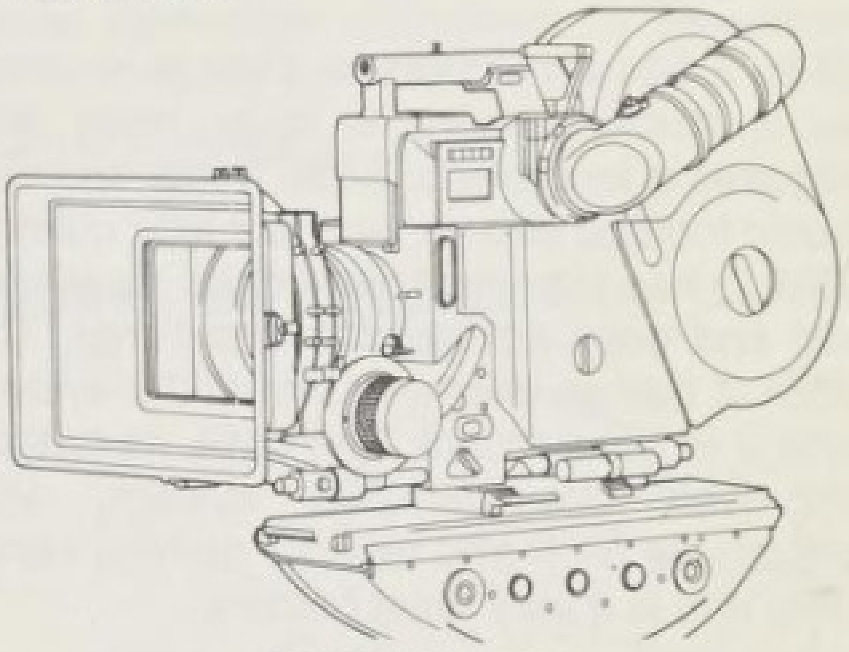
4.4 ARRIFLEX 765

A computer-age 65mm camera.

MOVEMENT: Dual three-pin pull-down movement with double registration pins.

SHUTTER: 180˚, mechanically variable 150˚ – 15˚ plus 144˚, 172.8˚ & 180˚ presettable.

VIEWFINDER: Standard orientatable viewfinder for tripod operation, offset viewfinder for hand-holding and 100% light to video for remote operation.



ARRIFLEX 765

LENS MOUNTING: Arri PL.

MOTORS, SPEEDS & POWER REQUIREMENTS: Two synchronized crystal controlled integral motors drive mirror shutter and film transport without any direct coupling. 2 – 100 fps crystal controlled, 15, 24, 25, 29.97, 30, 60, 75 & 100 fps presettable crystal controlled speeds, 24 fps in reverse. 24v up to 7Ah up to 30 fps, 14Ah above 30 fps.

FILM LOADING: 500 & 1000 ft. displacement magazines.

ADDITIONAL FEATURES: Many electronic control features.

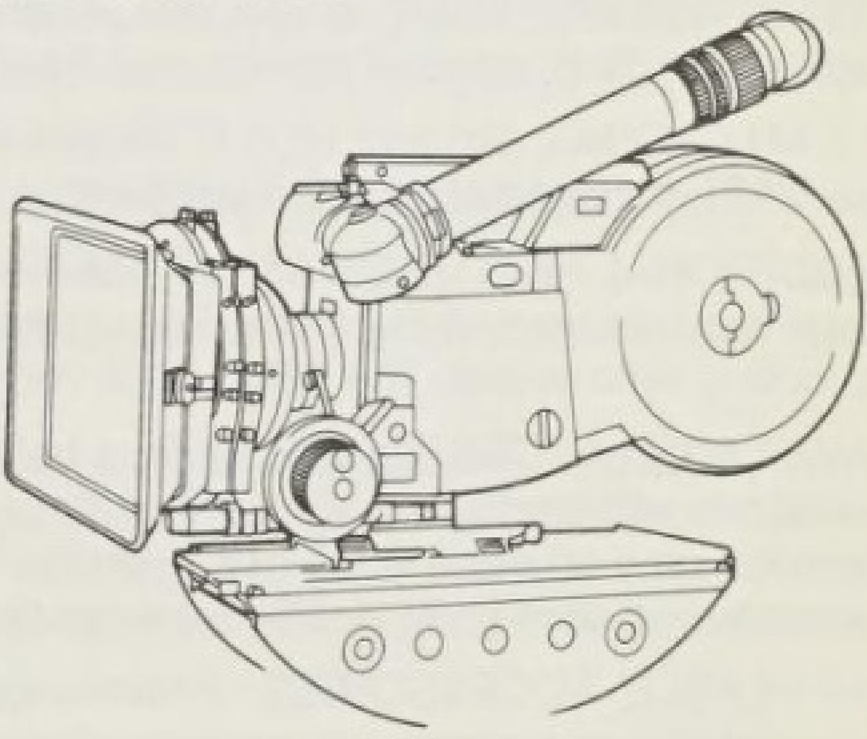
AVAILABLE ACCESSORIES: Video assist, remote control unit.

4.5 ARRIFLEX 535 & 535B

Arri's current state-of-the-art camera incorporating highly sophisticated electronic control systems. Very quiet.

The 535B model is a more basic version shorn of many of the integral electronic control accessories and other non-essentials. The variable shutter is manually adjustable and the viewfinder system is more simple and has a removable eyepiece system. It is both lighter and smaller.

MOVEMENT: 7-link movement with dual pin registration and pull-down.



ARRIFLEX 535

SHUTTER: Variable, 180˚ – 11˚. Adjustment may be synchronized with change in camera speed (not the available on the 535B version).

VIEWFINDER: Mirror Reflex. Eyepiece may be positioned almost anywhere around the camera. Short eyepiece available for hand-holding, long for tripod mounting. Video assist beamsplitter ratio may be set to 80:20, 50:50 or 0:100. On the 535B version the optical viewfinder system may be removed completely and only the video assist used.

LENS MOUNTING: Arri PL lens mount. No other is permitted.

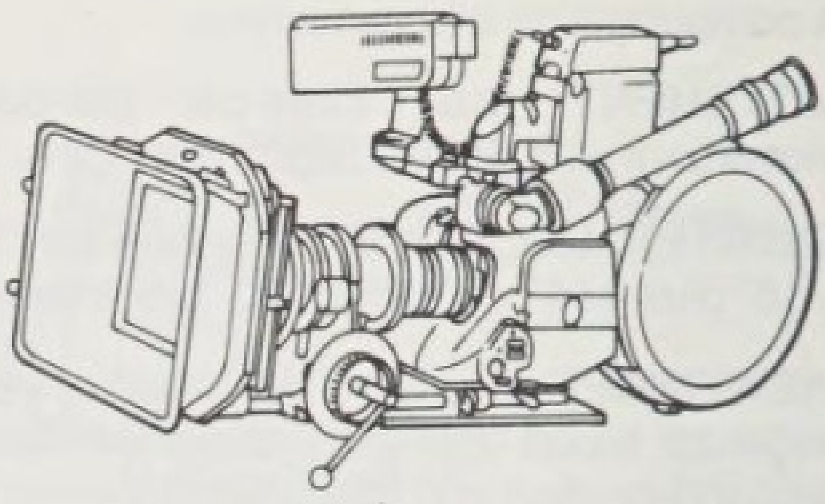
MOTORS, SPEEDS & POWER REQUIREMENTS: 24v DC, 3 – 50 fps (535B is 3 – 60 fps), selectable in 1/1000 fps increments from CCU or laptop computer and switchable at 24, 25, 29.97 & 30 fps.

FILM LOADING: 400 & 1000 ft co-axial magazines.

ADDITIONAL FEATURES: Programmable format reticle display and much else.

AVAILABLE ACCESSORIES: Color video assist, electronic camera control unit, swing-away matteboxes, time code module, etc. A Mac Powerbook program has been developed to remotely control all camera functions, including camera speed/shutter angle exposure control.

4.6 ARRIFLEX 35BL 1, 2, 3, 4 and 4s



ARRIFLEX 35BL

35BL 1 has a mechanical footage counter, as a studio camera is quite noisy and requires a lens blimp. 35BL 2 has an electronic footage counter and is a little quieter. 35BL 3 has improved electronics, is quieter still and does not need a lens blimp. The 35BL 4 has an improved viewfinder system and a PL lens mount. The 35BL 4s has an improved film transport system, with adjustable pitch and reverse running capability and is a very quiet camera.

MOVEMENT: 35BL 1 has four pull-down claws, the rest have two. All have two register pins. Interchangeable aperture plates.

SHUTTER: Early cameras are fixed 180° with 172.8° shutters also available. 35BL 3, 4 & 4s have 144°, 172.8° & 180° adjustable shutters.

VIEWFINDER: Spinning mirror reflex. Interchangeable ground glass. Eyepiece rotates through 125° with automatic horizon orientation.

LENS MOUNTING: 35BL 1 & 2 have a single port Arri SB mount, later models have Arri PL. BNCR and PV also available.

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 12v 24/25fps crystal controlled motor. Variable speeds to 50fps with external accessory. 35BL 1 may go to 100fps using 24v or 36v power supply and slight modifications to magazines. 35BL 1 may use 14v in cold with 1000ft. magazines. Motors draw 3.5 ah. at 24fps. 35BL 4 & 4s has adjustable pitch, reverse running and 3-perforation capability.

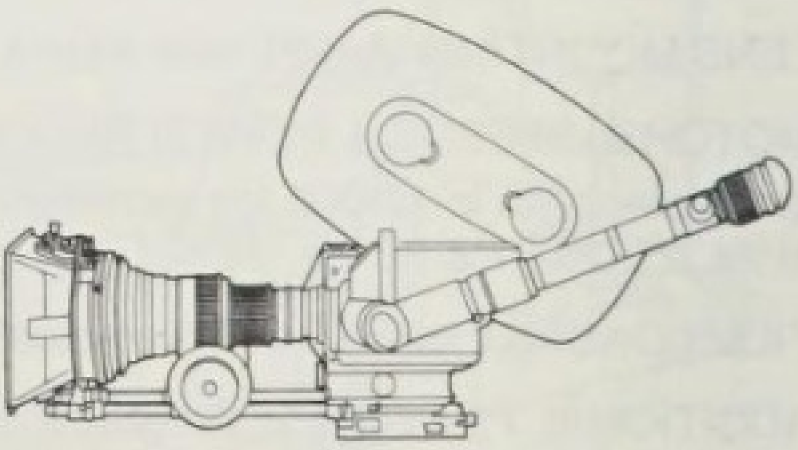
FILM LOADING: 400 and 1000 ft. magazines. Magazines are all backwards compatible, i.e. 35BL 4 magazines can be used with a 35BL 1 but not vice versa.

ADDITIONAL FEATURES: 35BL 1 has mechanical analogue fps and footage indicators, later versions have digital types. Lens blimps must be fitted to 35BL 1 & 2 cameras when shooting sync sound. The 35BL 4s is very quiet.

AVAILABLE ACCESSORIES Various balancing plate and long lens support systems, hand grip with start/stop switch, follow focus control, matte-box systems, phase advancer, remote sync to external source, variable speed control and remote switch electronic accessories, time code viewfinder extension video assist, etc.

AVAILABLE ACCESSORIES: Interchangeable camera doors with straight through, orientatable or periscope eyepieces otherwise as Arri 35BL except no interchangeable doors.

4.7 ARRIFLEX 35-3



ARRIFLEX 35-3

A 'next generation' version of the venerable Arri IIC.

MOVEMENT: Two pull-down claws and one register pin on one side of film only. Register pin engages in perforation two holes below the aperture. Interchangeable aperture plate. May be run forwards or backwards. Three perforation version also available.

SHUTTER: Early models have a fixed 180° shutter, a 172.8° also available. Later cameras have a 15 - 180° adjustable shutter which can be set to 144, 172.8 & 180° and 135° for reverse running.

VIEWFINDER: Spinning mirror reflex. Interchangeable ground glass. Interchangeable doors with optional orientatable, straight through and periscope viewfinder types.

LENS MOUNTING: Early cameras had a single ASB lens port. Later cameras have a PL port. BNC, Nikon and PV ports are also available.

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 12v DC crystal controlled 24/25/30 fps. Variable 5–50fps with internal (non-crystal) control, 5 – 130 fps with external accessory and 24v supply. Early models can run in reverse at 24/25 fps and later models 5 – 130 fps, with a 135° shutter.

FILM LOADING: 400 and 1000 ft. reversible magazines, 200 ft. non-reversible, 400 ft. co-axial magazines for hand holding and special lightweight magazines for Steadicam use are also available.

ADDITIONAL FEATURES: Digital footage and fps indicators.

4.8 ARRIFLEX IIC, IIC HS, IIC V & III C

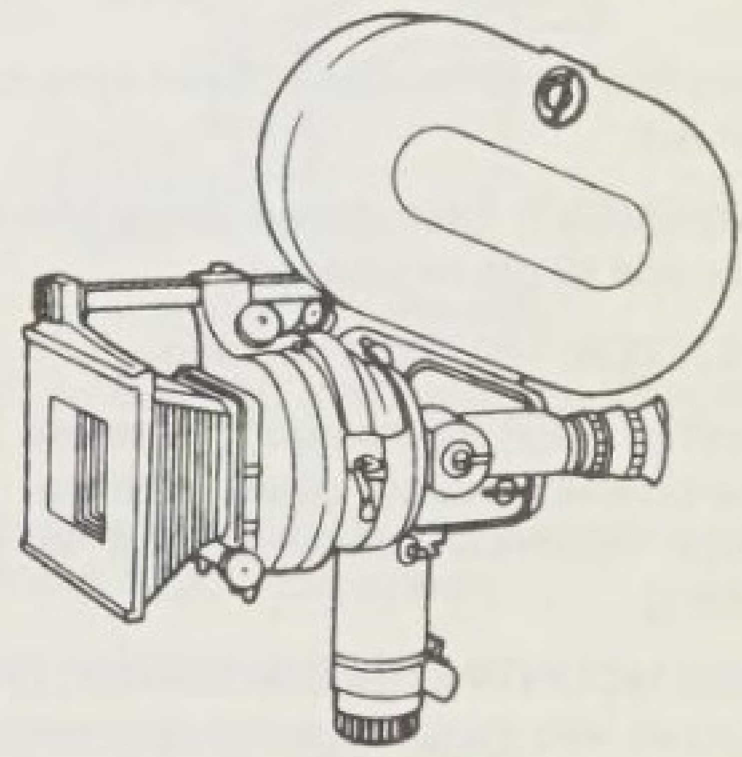
The archetypal go-anywhere, do-anything 35mm camera.

MOVEMENT: Single pull-down claw. Interchangeable aperture plate. May be run forwards or backwards.

SHUTTER: Fixed, 165° or 172.8°. IIC V has a 165° – 10° adjustable shutter.

VIEWFINDER: Spinning mirror reflex. Interchangeable ground glass. III C has Arri III type interchangeable doors.

LENS MOUNTING: Mk.I cameras have a three lens turret. One port usually SB, others AB. Many modified by other manufacturers to single port Arri SB, BNCR or PV.


ARRIFLEX IIC

MOTORS, SPEEDS & POWER REQUIREMENTS: Interchangeable 16v 24/25 fps crystal control, governed and variable speed motors which also act as the camera hand-grip and 110/220v 50/60 Hz, 24/25 fps synchronous motors which fit on a side mounting plate are all readily available. Model IIC HS may be used with an interchangeable 80 fps 32v DC motor. III C has a crystal controlled motor as standard.

FILM LOADING: 400 ft.(120m) reversible, 200 ft. (60m) non-reversible. Certain former models also took a special 1000 ft. (300m) magazine.

ADDITIONAL FEATURES: Sync pulse generator normally fitted. Mirrored shutter has a blacked-out center section to reduce flicker.

AVAILABLE ACCESSORIES: Periscope eyepiece, de-anamorphosing viewfinder, sound blimp, matte-box/sun-shade, sync marker light system, single shot motor adapter, heavy support, TV viewfinder, waterproof, heat resisting and sound deadening barneys, underwater housing. Many non-proprietary accessories and modifications also available.

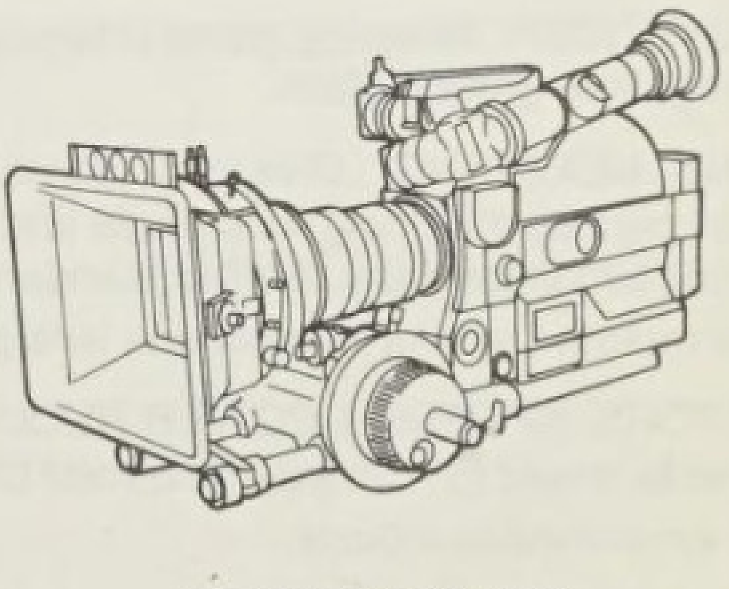
4.9 ARRIFLEX 16SR, 16SR-HS, 16SR-2, 16HSR-2, 16SR-3 & 16HSR-3

Compact, lightweight, versatile cameras for all types of 16mm filming. Early models are reasonably quiet, later models are very quiet.

MOVEMENT: Multi-link single pull-down claw and single register pin.

SHUTTER: 16SR & 16SR-2 have a 180° or 172.8° fixed opening shutter, 16SR-3 has a 90°/135°/144°/172.8°/180° adjustable shutter.

VIEWFINDER: Spinning mirror reflex, interchangeable fiber-optic ground glass, optional viewfinder extension. Viewfinder eyepiece may be rotated to right side of camera.


ARRIFLEX 16 SR3

LENS MOUNTING: 16SR & 16SR-2 models have Arri SB lens mounts and cannot accommodate lenses (principally wide angle & Cooke Kinetal types) with long back focal length. 16SR-3 has a PL mount which may easily be centered for Super-16. Lenses with special aperture control linkage needed if auto-exposure device is to be used.

MOTORS, SPEEDS & POWER REQUIREMENTS: 16SR-1 & -2 cameras have 12v DC crystal controlled (24/25fps) motor. 16SR-3 has a 24v motor. All model have 5 – 75 fps variable speeds and HS models operate at 10 – 150 fps. Early models have a Pilotone generator and auto-start marker. Phase Shift is an available accessory. 16SR-3 can be used with 535 type control accessories.

FILM LOADING: 400ft non-reversible, co-axial, quick-change, clip-on magazines. 16SR-3 magazines are available with a SMPTE time-code recording head incorporated.

ADDITIONAL FEATURES: Optional factory fitted accessories include TTL exposure control. On the 16SR-1 & -2 cameras Super 16 capability is a factory operation but on the 16SR-3 the adjustment is instantaneous.

AVAILABLE ACCESSORIES: Pan-handle on-off switch and variable speed controls, universal hand grip, video viewfinder, etc.

4.10 ARRIFLEX 16BL

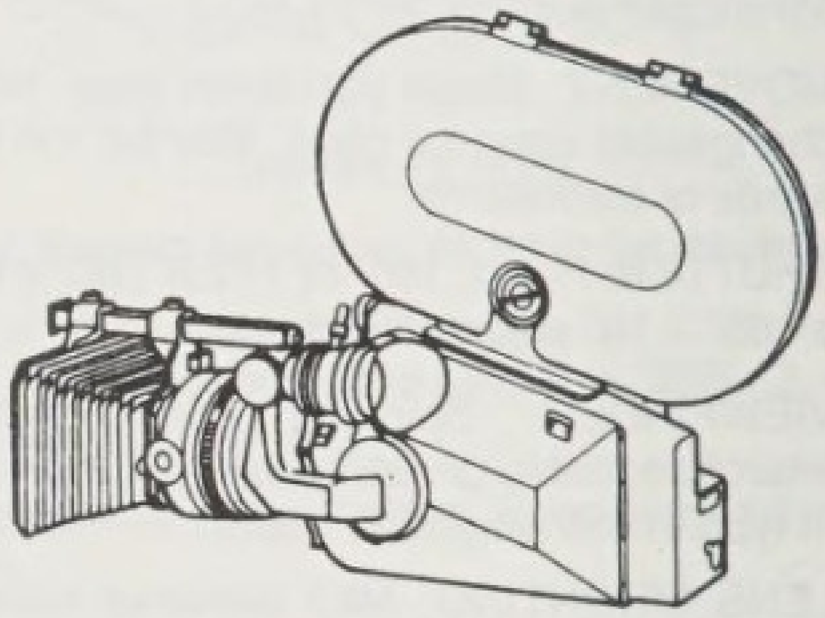
Arri's first hand-holdable 16mm sync-sound camera.

MOVEMENT: Cam driven single pull-down claw and single register pin.

SHUTTER: 180° fixed opening.

VIEWFINDER: Spinning mirror reflex, interchangeable ground glass, optional periscope viewfinder recommended for hand holding.

LENS MOUNTING: Arriflex standard or steel bayonet lens mount. Cannot accommodate lenses (principally wide angle & Cooke Kinetal types) with long back focal length.


ARRIFLEX 16BL

MOTORS, SPEEDS & POWER REQUIREMENTS: Various interchangeable 12v DC governor controlled (24/25fps) variable speed (5-50fps), crystal controlled (24/25fps) & 50/60Hz AC synchronous motors.

FILM LOADING: 400ft reversible displacement & 1200ft co-axial magazines.

ADDITIONAL FEATURES: Optional factory fitted accessories include non-interchangeable crystal controlled motor, pilotone generator, TTL exposure meter, auto slating, com-mag sound recording and Super 16.

AVAILABLE ACCESSORIES: Sound blimps, matte boxes, periscope viewfinder, phase advancer, single shot control, pistol hand grip, etc.

4.11 ARRIFLEX 16S, St & M

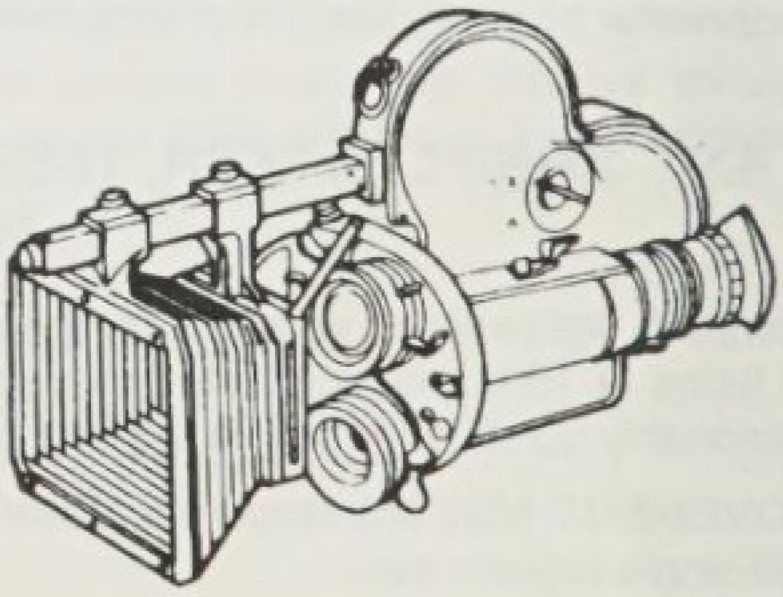
The most ubiquitous 16mm MOS camera ever made.

MOVEMENT: Cam driven single pull-down claw and single register pin.

SHUTTER: 180° fixed opening.

VIEWFINDER: Spinning mirror reflex, interchangeable ground glass.

LENS MOUNTING: Divergent three-lens turret permits mounting wide angle and long lenses simultaneously. Arriflex standard lens mount. On later models one lens port has an Arri steel bayonet insert.


ARRIFLEX 16

MOTORS, SPEEDS & POWER REQUIREMENTS: Interchangeable, various 8/12v DC variable speed (5 – 55 fps), governed (24/25fps), crystal controlled (24/25fps) & 50/60Hz AC synchronous motors.

FILM LOADING: Arri 16 S & St take 100ft (30m) daylight loading spools internally or 200 or 400ft displacement magazines. Arri 16M takes 200 & 400ft displacement and co-axial magazines only. Cameras and magazines may be run in reverse.

ADDITIONAL FEATURES: Optional factory fitted accessories include pilotone generator, TTL exposure meter, auto slating and Super 16.

AVAILABLE ACCESSORIES: Sound blimps, matte boxes, periscope viewfinder, phase advancer, single shot control, pistol hand grip, etc.

4.12 AURICON (VARIOUS MODELS)

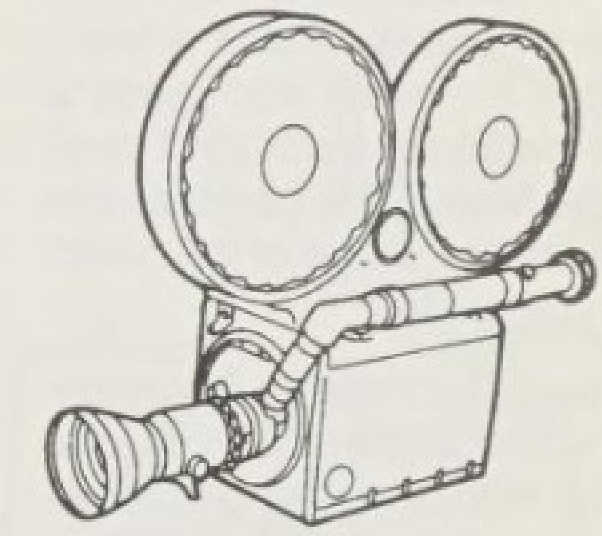
Reliable, rugged, self-blimped 16mm cameras incorporating facilities for com-mag and com-opt sound recording.

MOVEMENT: single pull-down claw, ball-bearing film gate, spring-loaded pressure pad.

SHUTTER: Fixed opening, 173° or 175°. TV-T models have a very precise 144° shutter.

VIEWFINDER: Non-reflex. Usually used with a reflex type Angenieux zoom lens.

LENS MOUNTING: 'C' mount.



AURICON Pro 600

MOTORS, SPEEDS & POWER REQUIREMENTS: Internal AC synchronous. Suitable power packs convert for 12v DC operation.

FILM LOADING: Cinevoice model takes 100ft daylight spools but usually converted for 400ft displacement magazines. Others take 400, 600 & 1200ft magazines.

ADDITIONAL FEATURES: Super 1200 has an internal focusing system.

AVAILABLE ACCESSORIES: Plug-in com-mag & com-opt recording heads.

4.13 BEAULIEU R16

A useful utility camera for documentary and wild shooting.

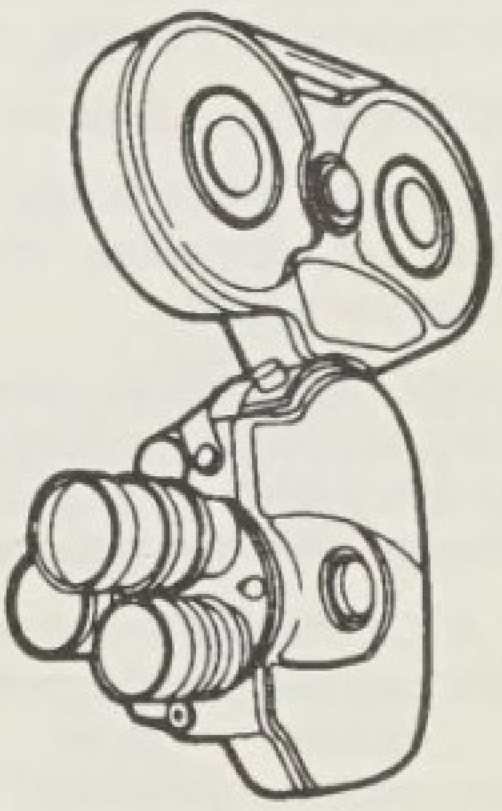
MOVEMENT: Single pull-down claw.

SHUTTER: Guillotine (up and down) type shutter. Exposure approx. 1/60 sec at 24 fps.

VIEWFINDER: Reflex mirror attached to the shutter. Non-interchangable ground-glass.

LENS MOUNTING: Three-lens turret or single heavy duty lens mounting.

MOTORS, SPEEDS & POWER REQUIREMENTS: Internal 7.2v DC motor (2 - 64 fps). Battery incorporated in hand-grip. May be run in reverse with internally loaded film only.



BEAULIEU R16

FILM LOADING: Internal 100ft daylight loading or external 200ft magazine.

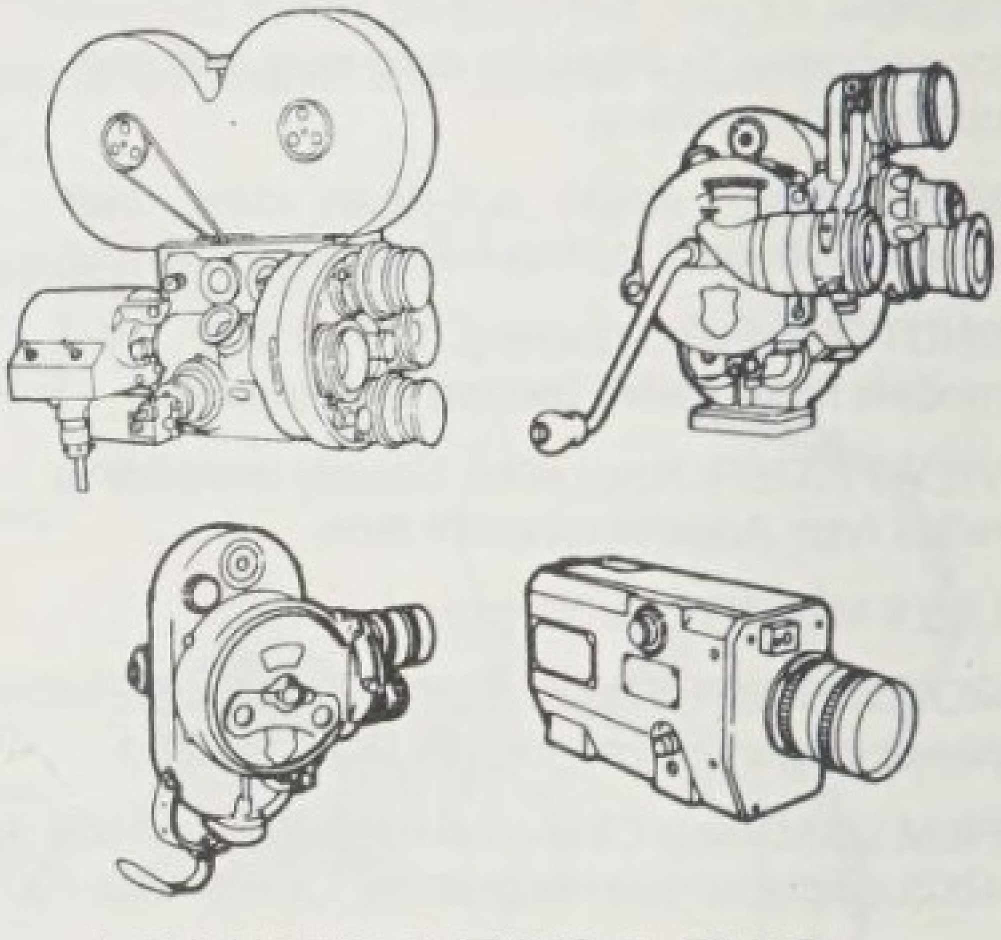
ADDITIONAL FEATURES: TTL exposure meter, single shot capability.

AVAILABLE ACCESSORIES: Pilotone generator.

4.14 BELL & HOWELL (VARIOUS MODELS)

No list of professional cameras would be complete without a mention of Bell & Howell who made a range of cameras from 1912 until the 1960s. Many B&H cameras are still in use today, some of them well over 50 years old.

Among the most notable examples are the Model 2709 (still in use for animation, high-speed and process cinematography and for optical printing), the 35mm Eymo (the classic action camera of World War II), the 16mm Filmo (probably the most successful amateur camera) and the miniscule 16mm Minicam-16 POV camera (developed from a GSAP gun camera).



1. B & H 2709; 2. EYMO; 3. FILMO; 4. MINICAM-16

4.15 BOLEX H16

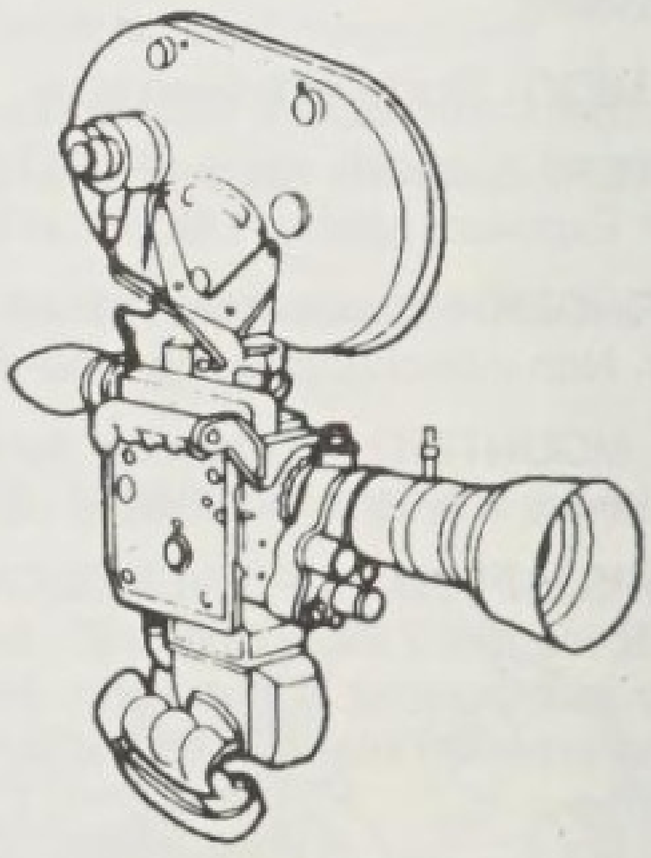
A range of utility cameras much used for scientific and documentary filming.

MOVEMENT: Single claw pull-down.

VIEWFINDER: Reflex prism diverts 35% of light to viewfinder. Exposure must be increased to compensate.

FILM LOADING: All cameras take 100ft daylight loading spools. Some (see below) may be used with a 400ft magazine. Spool loaded film may be rewound in camera.

AVAILABLE ACCESSORIES: Bellows sunshade, crystal control, electric motors for clockwork models, fader unit, intervalometer, pilotone generator, remote control, sound barney, synchro-flash relay, underwater housings, video viewfinder, wide angle lens attachment, etc.



BOLEX H16

H16	M-5	RX-5	SB	SBM	EBM	EL
Single 'C' lens mount	X					
Triple 'C' mount lens turret		X				
Single bayonet lens mount			X	X	X	X
Prism block reflex viewfinding		X	X	X	X	X
Clockwork drive	X	X	X	X		
Integral 12v electric motor					X	X
Usable with 400ft external magazines	X	X	X		X	X
Gelatine filter holder		X	X	X	X	X
Adjustable shutter		X	X	X		
Max. shutter opening (°)	133	133	133	133	170	170
Automatic TTL exposure control						X

4.16 CINEMA PRODUCTS CP-65

A sophisticated 65mm camera developed for Showscan and reasonably quiet even at 60 fps.

MOVEMENT: Compensating link with dual registration pins and four pull-down claws.

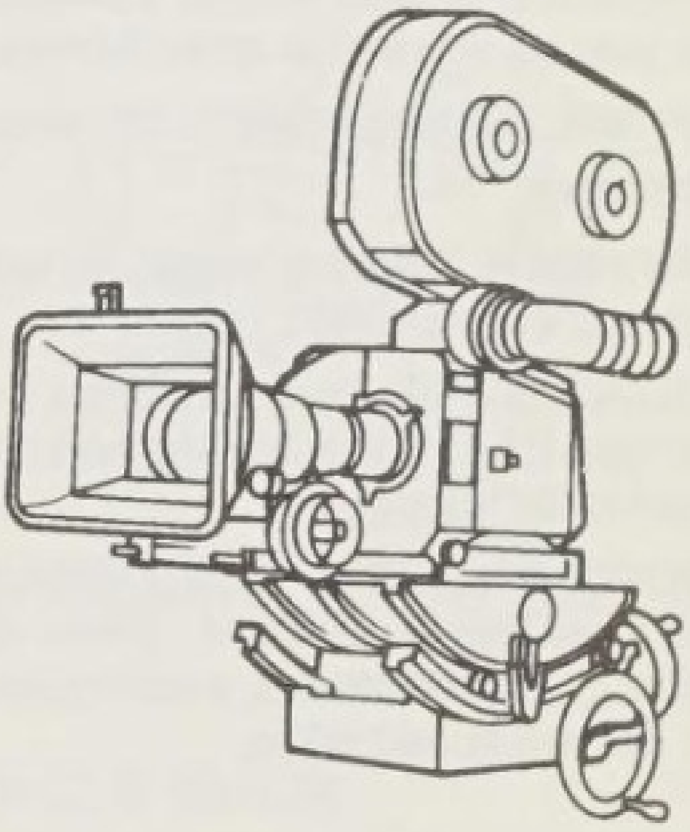
SHUTTER: Fixed opening 170°.

VIEWFINDER: Mirror shutter through the lens viewfinding with all facilities.

MOTORS, SPEEDS & POWER REQUIREMENTS: 1 - 72 fps, crystal controlled at all speeds, forward or reverse Single shot capability.

FILM LOADING: 1000 and 2500ft magazines.

ADDITIONAL FEATURES: Provision for behind-the-lens filter.



CINEMA PRODUCTS CP-65

AVAILABLE ACCESSORIES: External control for phase locking for process and 3D cinematography.

4.17 CINEMA PRODUCTS CP-16

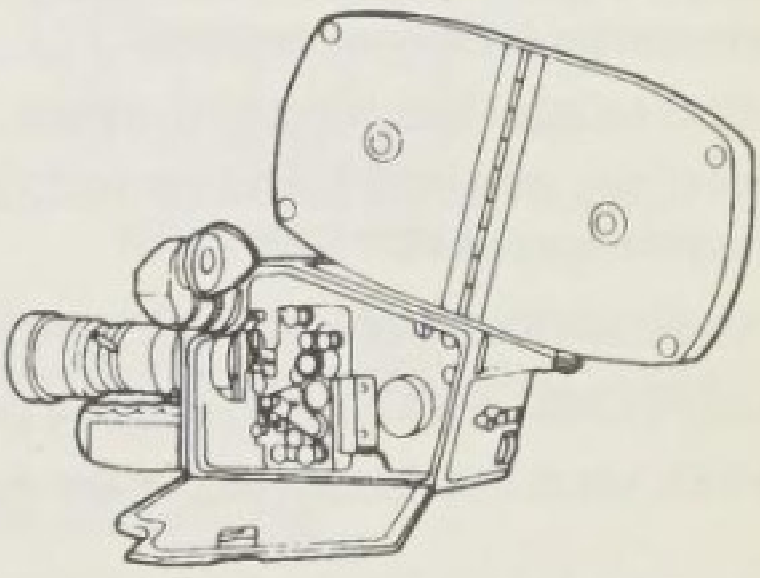
A range of cameras developed from the Auricon Cinevoice. Before the portable TV camera was the workhorse of TV news gathering.

MOVEMENT: Auricon type (see Section 4.12).

VIEWFINDER: Non-reflex models use Angenieux reflex type zoom lenses.

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 20v motor. Battery pack sufficient to run 2000ft of film and the power amplifier slots into side of camera.

FILM LOADING: 400ft magazine.



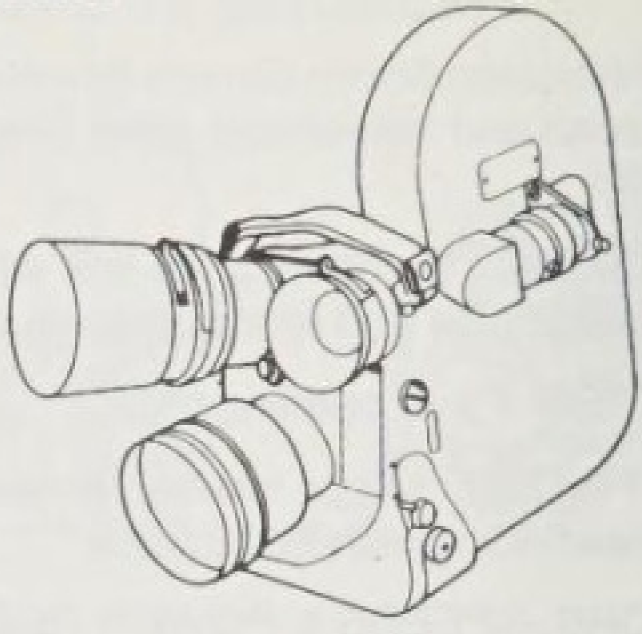
CINEMA PRODUCTS CP-16

ADDITIONAL FEATURES: Provision for behind-the-lens filter.

AVAILABLE ACCESSORIES: On-board sound recorder, magnetic recording head, VU meter visible to the cameraman, orientatable viewfinder, viewfinder extension, etc.

CP	16	16/A	16R	16R/A	16R/ADS
Non-reflex	X	X			
180° shutter	X	X			
156° or (later models) 170° shutter			X	X	X
'C' lens mount	X	X			
CP (miniature BNCR) lens mount			X	X	X
Sep-Mag capability			X	X	X
Com-Mag capability			X	X	
Integral Com-Mag amplifier			X	X	

4.18 ECLAIR CM3



ECLAIR CM3

Innovative French camera from the mid 1940s.

MOVEMENT: Double ratchet pull-down claws. Plate may be masked to other formats.

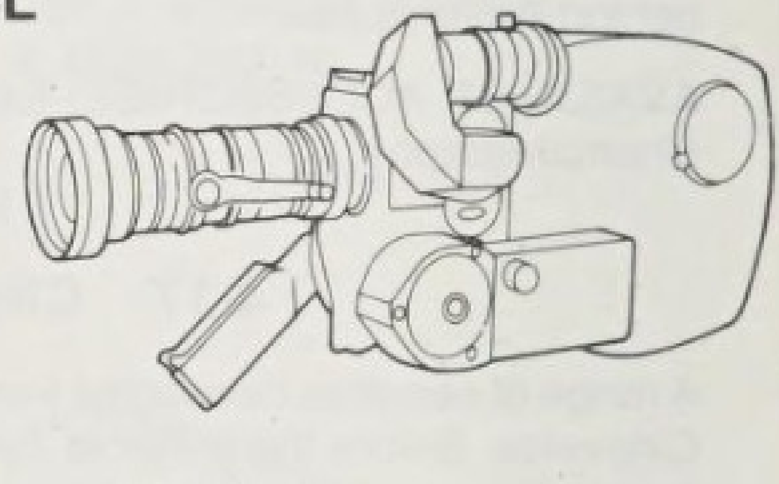
SHUTTER: Adjustable 200° – 40° while camera is stationary.

VIEWFINDER: Spinning mirror. Eyepiece may be rotated through 360°.

LENS MOUNTING: Divergent three lens turret. Eclair type CA lens mount. One port sometimes off-center for 'scope'.

MOTORS, SPEEDS & POWER REQUIREMENTS: Interchangeable. 6/8v variable speed which draw 9ah is standard. 24fps 12 & 24v crystal controlled, AC synchronous, and single shot electric motors, a spring drive motor and a hand turn device are also available. Max. camera speed 40fps.

4.19 ECLAIR ACL



ECLAIR ACL

A particularly compact, simple and quiet 16mm camera without frills.

MOVEMENT: Single pull-down claw.

SHUTTER: 175° focal plane shutter.

VIEWFINDER: Side to side oscillating mirror, orientatible viewfinder eyepiece.

LENS MOUNTING: Mostly 'C' mount.

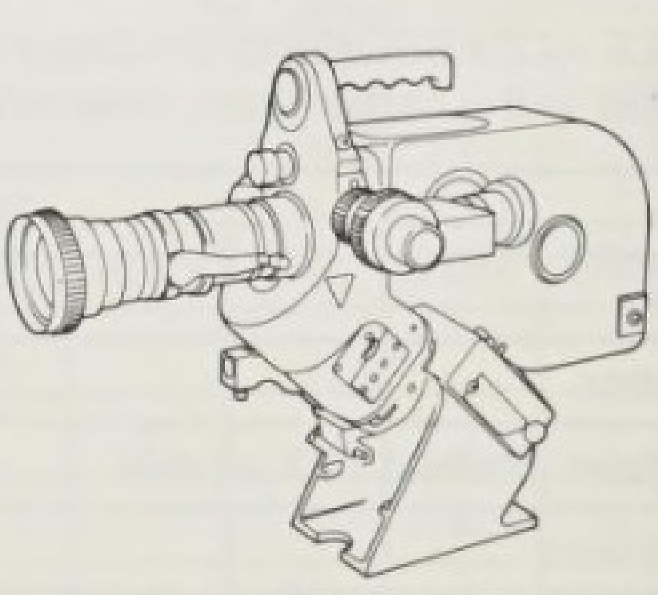
MOTORS, SPEEDS & POWER REQUIREMENTS: 12v DC crystal control or incremental variable speeds (8–75fps).

FILM LOADING: 200 and 400ft clip-on co-axial magazines.

ADDITIONAL FEATURES: Pilotone module, provision for behind-the-lens filtering.

AVAILABLE ACCESSORIES: Com-mag sound recording, high speed charging.

4.20 ECLAIR NPR



ECLAIR NPR

Introduced in 1960, was the first quiet, hand-holdable, sync-sound film camera. It revolutionized film making.

MOVEMENT: Single claw pull-down with a film stabilizing register pin.

SHUTTER: 180° adjustable to 5° while the camera is stationary.

VIEWFINDER: Spinning mirror reflex. Standard eyepiece rotates through 360° but does not correct horizon orientation. Auto correcting eyepiece an available accessory.

LENS MOUNTING: Two lens turret, usually 1 × 'C' mount, the other Arri or Eclair.

MOTORS, SPEEDS & POWER REQUIREMENTS: 12v DC, crystal controlled, with pilotone output. Can also be run at 4-40 fps variable speeds.

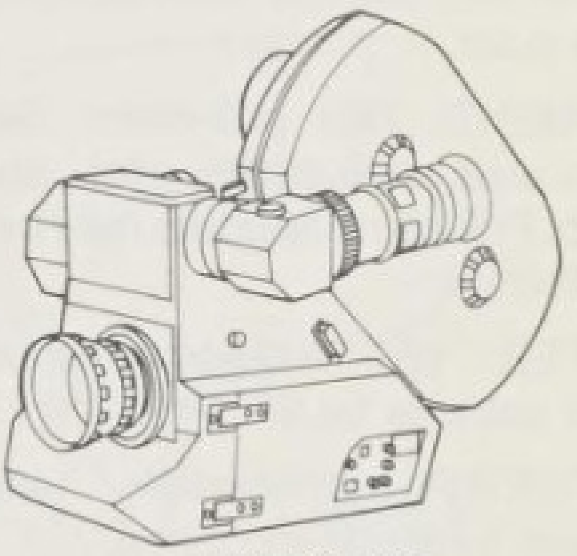
FILM LOADING: Clip on 400 ft co-axial magazines.

ADDITIONAL FEATURES: Automatic sync-marker light

4.21 FRIES ENGINEERING (VARIOUS MODELS)

A series of 65mm, 35mm and Vistavision register pin cameras of high precision used for SFX work.

MOVEMENT: Mitchell Std. or High Speed type.



FRIES 435

VIEWFINDER: Spinning mirror reflex, register pins on ground glass for film clip, orientatable viewfinder, video assist, etc.

LENS MOUNTING: Any.

MAGAZINES: Depending upon the model, Mitchell type or special.

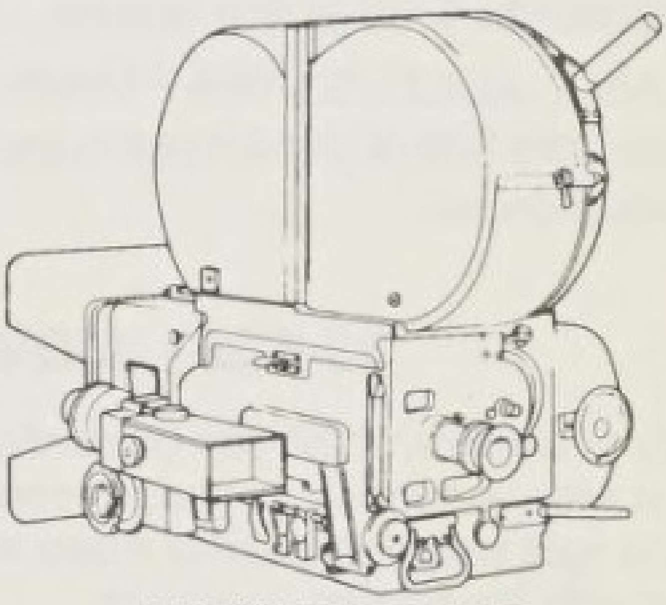
MOTORS, SPEEDS & POWER REQUIREMENTS: Depending upon the model, stop frame to 150fps forward and 5fps in reverse.

4.22 MITCHELL NC, BNC & BNCR

The established Hollywood type studio cameras of the 1930s, 1940s and 1950's. Will never wear out.

MOVEMENT: Four pull-down claws, two register pins. Aperture plate may be masked to any format. Runs forwards or backwards.

SHUTTER: Focal plane shutter. Variable 175° – 0° while camera is running. In camera automatic fades and mixes are also possible.



MITCHELL BNCR

VIEWFINDER: Early models had 'rack-over' focusing and an auto parallax viewfinder. BNCR model incorporates a spinning mirror reflex system independent of the light shutter. Viewfinder incorporates image magnification and 2 × contrast filters.

LENS MOUNTING: Single port BNCR positive clamp and lock ring.

MOTORS, SPEEDS, POWER REQUIREMENTS: Interchangeable. 110v 60Hz or 220v 50Hz synchronous, 110v AC/DC multi-duty, 24v DC, non-proprietary 24/25fps 36v crystal control with pre-set variable speeds.

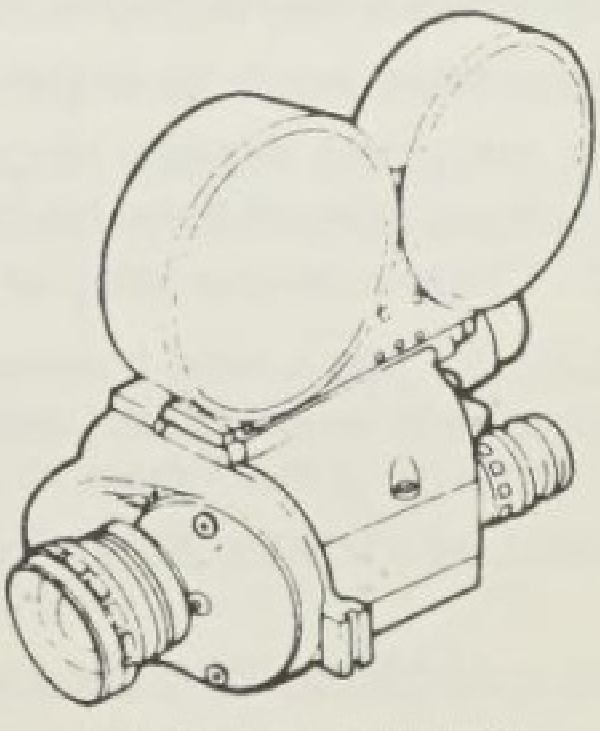
4.23 MITCHELL S35 MKII

Hollywood's first attempt at a mirror reflex camera.

MOVEMENT: Four pull-down claws, two register pins. Aperture plate may be masked to any format.

SHUTTER: Focal plane shutter independent of mirror. Variable 170° – 0° while camera is running.

VIEWFINDER: Spinning mirror reflex incorporating magnifier and 2 × viewing filters. Interchangeable ground glass. Special door with orientatible viewfinder eyepiece may be fitted.



MITCHELL S35 MKII

LENS MOUNTING: Single port, or three-lens Mitchell S35 lens mount or single port BNCR. Also modified for Panavision.

MOTORS, SPEEDS & POWER REQUIREMENTS: Interchangeable motors, 24v DC governor controlled and 115v AC/DC 16–32fps variable speed. Proprietary or non-proprietary 36v 24/25fps crystal controlled and 12, 16, 20 and 25fps pre-set variable speeds. 115v 60Hz 24fps, 115 or 220v 50Hz 24 or 25fps single or three phase synchronous. 24v AC/DC or 200/240v AC 24 - 128fps high speed. 115/220v AC single shot.

4.24 MOVIECAM SUPERAMERICA

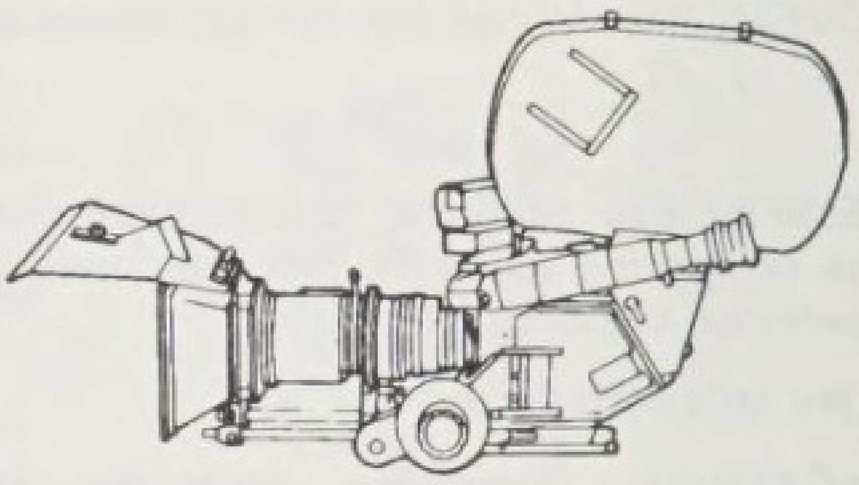
A feature-film camera from Austria. Exceptionally quiet.

MOVEMENT: Two pull-down claws, two register pins. Adjustable pitch and stroke controls. Full frame aperture may be masked to any format.

SHUTTER: 180° adjustable shutter with positive settings for 90, 144, and 172.8.

VIEWFINDER: Orientatible reflex with extension for tripod mounting.

LENS MOUNTING: Arri SB & PL, BNCR.



MOVIECAM SUPERAMERICA

MOTORS, SPEEDS & POWER REQUIREMENTS: 24v DC or 120/220v AC, 12 – 32 fps microprocessor controlled in 1 fps increments. 24/25 crystal controlled.

FILM LOADING: 500 and 1000 ft displacement magazines.

ADDITIONAL FEATURES: Automatic slate, field replaceable electronic circuit boards, internal camera & magazine heaters,

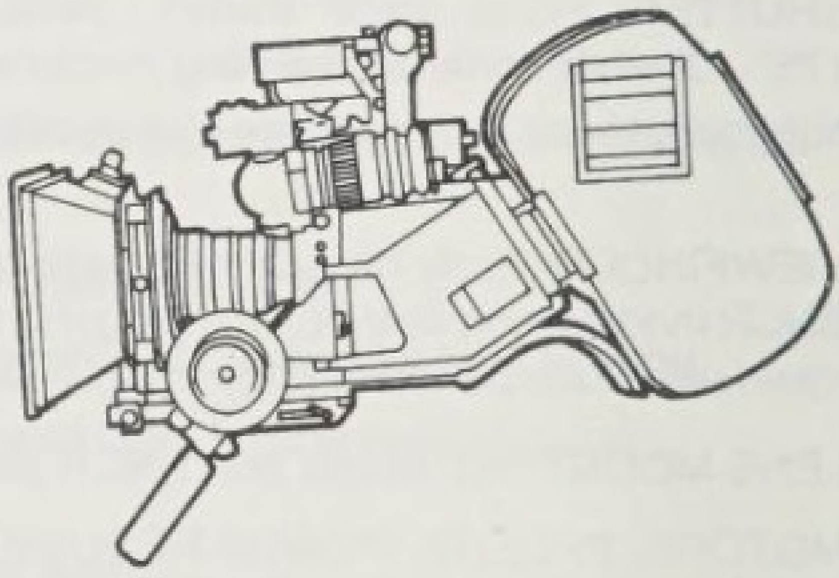
AVAILABLE ACCESSORIES: 'Moviespeed' attachment allows programmable speed changes from 1 to 50 fps forwards and 12 – 32 fps in reverse with automatic exposure compensation, etc.

4.25 MOVIECAM COMPACT

A modular camera which can be configured to suit a wide variety of usages. Its compact size and light weight capability make it very popular with Steadicam operators.

MOVEMENT: Two pull-down claws, two register pins. Adjustable pitch and stroke controls. Full frame aperture may be masked to any format.

SHUTTER: Adjustable shutter attached to the rear of the reflex mirror. Positive settings for 45, 90, 120, 144, 172.8 and 180° shutter openings.



MOVIECAM COMPACT

VIEWFINDER: Modular viewfinder, can be configured with long eyepiece for tripod usage, short eyepiece for hand-holding, set on the right-hand side of the camera or removed altogether and replaced by a lightweight video for Steadicam and remote-control usage. Luminous frameline may display multiple formats simultaneously.

LENS MOUNTING: Arri PL or BNCR.

MOTORS, SPEEDS & POWER REQUIREMENTS: May be operated off 24v battery or, using an optional Power Supply Unit, off 110V/220V AC. 12 – 32 fps crystal control, 2 – 50 fps or 12 – 32 fps in reverse using an optional Speed Control accessory.

FILM LOADING: 500 & 1000 ft normal magazines, 400 ft lightweight plastic magazine for Steadicam and remote control usage. By the use of adaptors normal magazines may be mounted on top of the camera for studio usage or on the rear for hand-holding.

ADDITIONAL FEATURES: Easy interchange between normal and Super 35 configuration.

AVAILABLE ACCESSORIES: Color and B&W video assists, Aäton timecode available.

4.26 NAC E-10

A 300 to 10,000 fps high speed camera which makes all other high speed cameras look pedestrian.

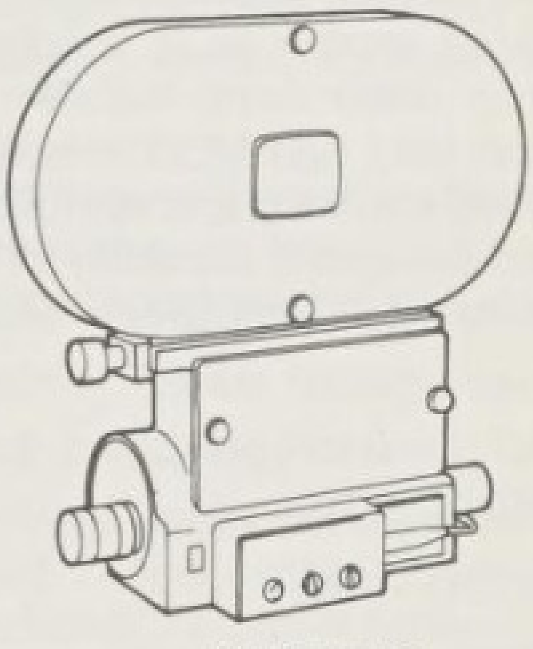
MOVEMENT: Continuous recording using a 4-sided rotating prism.

SHUTTER: 72° rotating disk.

VIEWFINDER: Reflex viewing prism (requires 1/3 stop exposure increase).

LENS MOUNTING: 'C'. Nikon optional.

MOTORS, SPEEDS & POWER REQUIREMENTS: 115v AC (300 – 500 fps), 230v AC (300 – 10000 fps). With 8 or 16 sided prisms and appropriate shutters and smaller aperture plates, frame rates of 600 – 20000 fps and 1200 – 40000 fps are possible.



NAC E-10

FILM LOADING: 400 ft spool loading magazines. Above 7,000 fps film must be wound onto balanced spools. Up to 5000 fps long-pitch double row perforated (2R-3000) is preferred, above 5000 fps short-pitch (2R-2994) must be used.

AVAILABLE ACCESSORIES: Event synchronization, LED timing lights, TTL exposure control.

4.27 PANAVISION PANAFLEX 65

MOVEMENT: Dual three-pin pull-down movement with double pin registration.

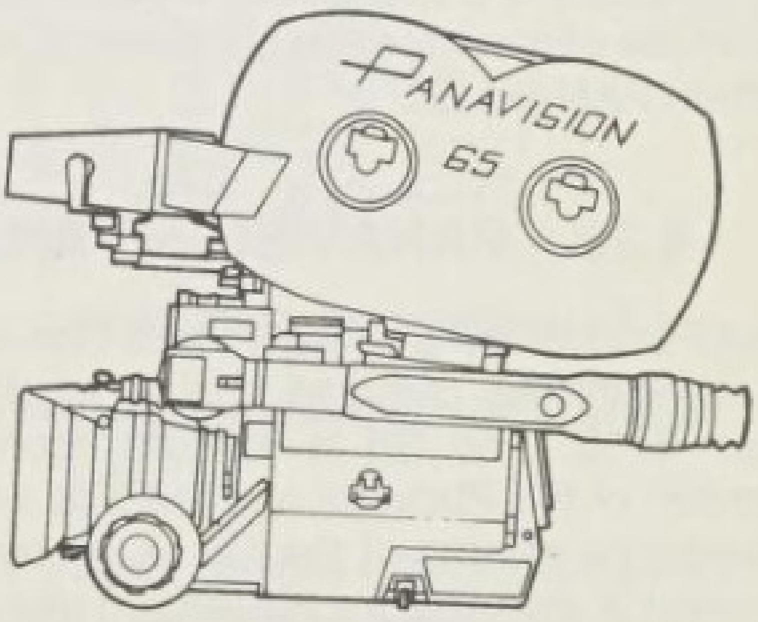
SHUTTER: 180°, mechanically variable 150° – 15° plus 144°, 172.8° & 180° presettable.

VIEWFINDER: Standard orientatible viewfinder for tripod operation, offset viewfinder for hand-holding and 100% light to video for remote operation.

LENS MOUNTING: Panaflex.

MOTORS, SPEEDS & POWER REQUIREMENTS: 24v DC, 4 – 36 fps

FILM LOADING: 500 & 1000 ft displacement magazines.



PANAVISION PANAFLEX 65

ADDITIONAL FEATURES: Internal camera and magazine heaters, in-field replaceable electronic boards.

AVAILABLE ACCESSORIES: Video assist, remote control unit, accepts almost all PLATINUM PANAFLEX 35 accessories.

4.28 PANAVISION 65mm HAND-HOLDABLE & HIGH-SPEED

65mm reflex camera supplied either with a spinning-mirror shutter or in a lightweight pellicle mirror reflex form. Suitable for all general hand-held and MOS shooting, for Steadicam and Louma crane operation, and with a maximum speed capability of 72 fps, is also suitable for high-speed cinematography.

MOVEMENT: Dual fork pull-down, dual pilot pin registration.

SHUTTER: 170° fixed.

VIEWFINDER: Spinning mirror or pellicle reflex models available. The latter is lighter in weight but requires an extra 1/2 stop exposure.

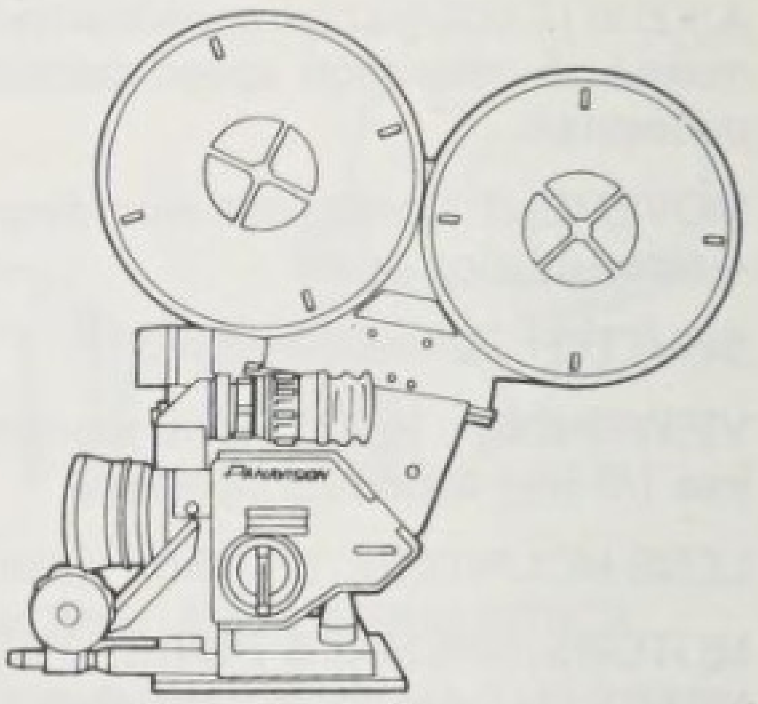
LENS MOUNTING: Panavision.

MOTORS, SPEEDS & POWER REQUIREMENTS: 24v DC, 4 – 72 fps.

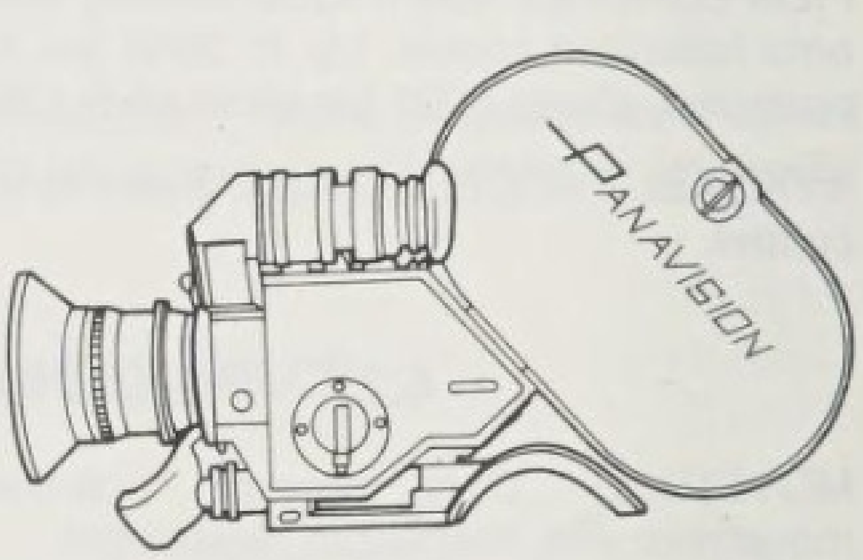
FILM LOADING: 250, 500 & 1000 ft. magazines.

ADDITIONAL FEATURES: Internal camera and magazine heaters, in-field replaceable electronic boards.

AVAILABLE ACCESSORIES: Video assist, remote control unit. Utilizes the same lenses, batteries and many other accessories as the 65mm PANAFLEX.



PANAVISION 65mm HAND-HOLDABLE & HIGH-SPEED CAMERA
Spinning mirror reflex version

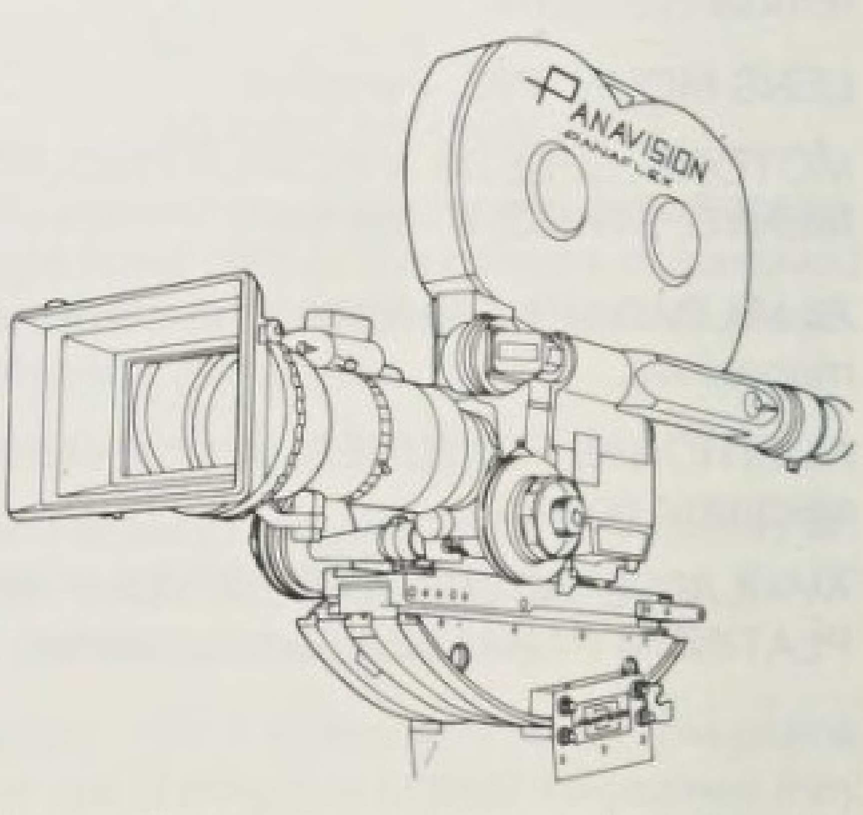


PANAVISION 65mm HAND-HOLDABLE & HIGH-SPEED CAMERA
Lightweight pellicle mirror reflex version

4.29 PANAVISION PANAFLEX 35 PLATINUM, GII AND X

The Platinum is Panavision's top of the range state-of-the-art cameras. Noise level less than 20dB. The GII is a more economic version of the Platinum and the X is a fixed viewfinder version of the GII. A lightweight version is available for Steadicam use.

MOVEMENT: Two pull-down claws and two register pins. Register pins engage in the same holes (immediately below the frame line) as optical printers. 4-Perf and 3-Perf models are available. Full frame aperture plate is standard, may be masked to any other format.



PANAVISION PLATINUM PANAFLEX 35

SHUTTER: Focal plane shutter independent of reflex mirror. Infinitely adjustable 200° – 50° while camera is running. Positive settings for 144°, 178.8° and 180°. Micrometer adjustment allows critical synchronization with computers, TV monitors and HMI lights at unusual frame rates. Manual and electronic remote control units available.

VIEWFINDER: Spinning mirror reflex interchangeable with pellicle mirror reflex when optimum Video viewfinder image quality is required. Image magnification, 2 × contrast filters and de-anamorphoser. Fully rotatable eyepiece with automatic horizon orientation. Long and medium length extension eyepieces may be linked to tilt head for constant position view-finding. 'Panaglow' illuminated ground glass reticle shows up bright red when filming against black background. Interchangeable ground glasses. 'Panaclear' heated eyepiece. Entire viewfinder system may be removed and replaced by a miniature 'Panavid' video viewfinder for lightest possible camera weight.

LENS MOUNTING: Single port, Panavision positive clamp & lock ring. Provision for behind-the-lens filtering.

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 24v crystal controlled at any speed (4 – 36fps). All electronic control boards easily interchangeable in case of malfunction. Accessories available to synchronize automatically with Process Projector, Video or other external source. Internal camera heaters ensure trouble-free camera operation in the very coldest conditions possible.

FILM LOADING: 250 and 500 ft types may be fitted on top or rear of camera for hand holding or low profile operation, 1000 and 2000 ft types may be fitted to top of camera for location or studio operation. 1000 ft reverse running magazines available on request.

ADDITIONAL FEATURES: Hand holding attachments. Digital footage counter and tachometer. Large focus control knobs.

AVAILABLE ACCESSORIES: 'Panaflasher' light overlay image contrast control, 'Panalite' camera mounted light which may be dimmed in shot without changing color temperature, 'Panahead' lightweight geared gyro/free head, 'Panapod' lightweight tripod, 'Panatate' turnover mount, Nodal adapter for mounting camera nodally, 'Panatape' ultrasonic distance measure, 'Panavid' color or B&W Video Assist systems, 'Panaglide' floating camera system, Panavision 'Aätoncode' Time Code system, Environmental protection equipment, etc.

4.30 PANAVISION PANASTAR

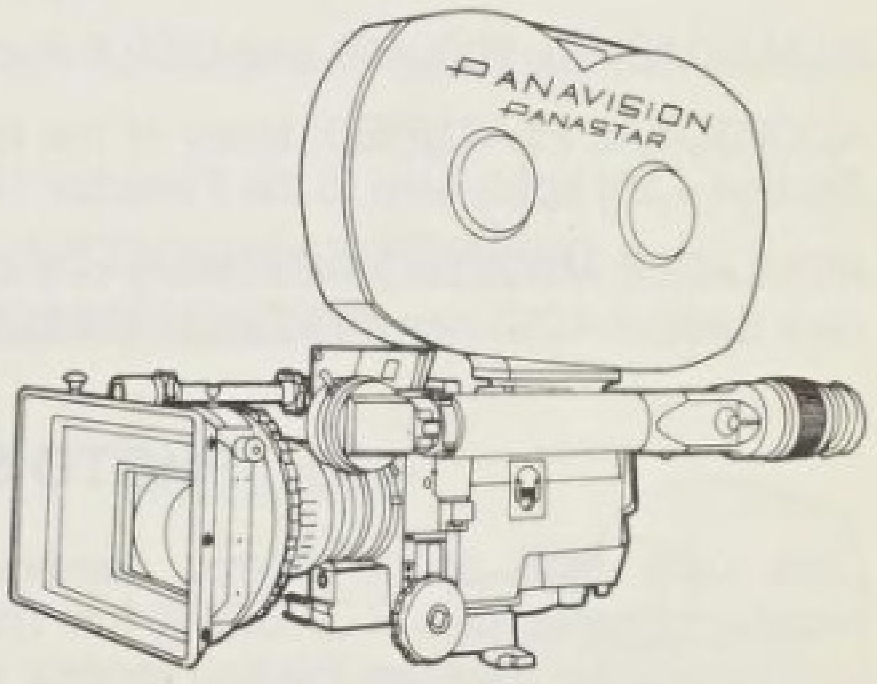
High speed (6 – 120 fps) member of the Panaflex family of cameras. Much used for SFX work.

MOVEMENT: Four pull-down claws two register pins.

SHUTTER: Focal plane shutter independent of mirror adjustable 180° × 50° while camera is running. Positive settings for 144 and 172.8°.

VIEWFINDER, LENS MOUNTING: As Golden Panaflex.

MOTORS, SPEEDS & POWER REQUIREMENTS: As Golden Panaflex.



PANAFLEX PANASTAR

FILM LOADING: 1000ft 'High Speed' magazines incorporating automatic film tension.

ADDITIONAL FEATURES: As Platinum Panaflex.

AVAILABLE ACCESSORIES: As Platinum Panaflex. In shot camera speed changes with exposure, compensation may be accomplished with the 'Panafade' accessory.

4.31 PANAVISION SUPER R200

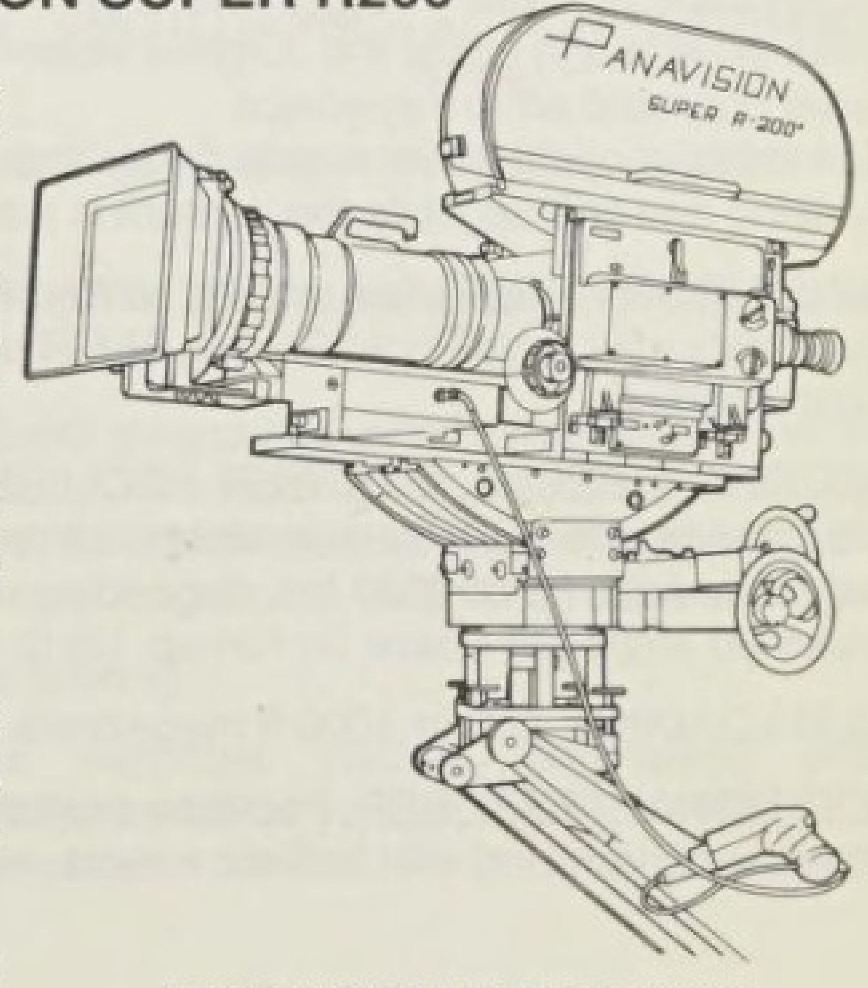
Mitchell NC and BNC camera mechanisms fitted with mirror shutters and many other refinements.

MOVEMENT: Four pull-down claws, two register pins. Adjustable pitch control. Full frame aperture may be masked to any format. May be run forwards and backwards.

SHUTTER: Focal plane shutter independent of reflex mirror, adjustable 200° – 50° while camera is running.

VIEWFINDER: Spinning mirror reflex incorporating image magnification, two contrast filters and de-anamorphoser. Interchangeable ground glass.

LENS MOUNTING: Single port. Panavision positive clamp and lock ring lens mount.



PANAVISION SUPER R200

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 24 or 36v 24/25fps crystal controlled and 12 – 32 fps variable speed motors.

FILM LOADING: 400ft & 1000ft magazines with appropriate sized magazine housings.

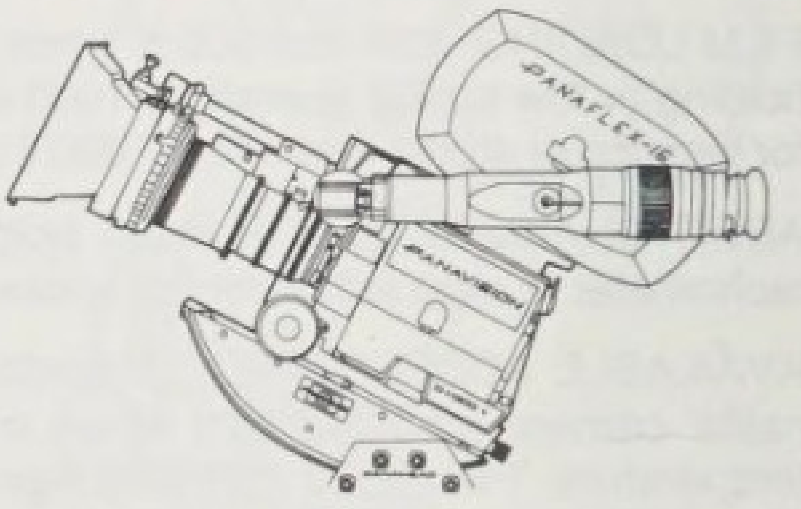
ADDITIONAL FEATURES: Self blimped, behind the lens filtering, large follow focus control.

4.32 PANAVISION PANAFLEX 16

A studio type 16mm camera incorporating many of the sophistications of the Panavision 35mm system. Mainly used for high class drama production.

MOVEMENT: Single claw, dual registration pin (above and below the aperture), removable aperture plate, removable movement.

SHUTTER: Focal plane, independent of the reflex mirror. 180°, adjustable to 40° while the camera is running.



PANAVISION PANAFLEX 16

VIEWFINDER: Rotating mirror independent of the light shutter. Left eye/right eye viewing facility. Short eyepiece available for hand holding, long for tripod mounted shooting.

LENS MOUNTING: Panavision 16 bayonet.

MOTORS, SPEEDS & POWER REQUIREMENTS: Integral 24v crystal controlled/variable speed (4 – 50 fps) motor.

FILM LOADING: 200, 400 and 1200 ft displacement magazines.

ADDITIONAL FEATURES: Many of the features listed for the Platinum Panaflex (see Section 4.29) apply also to the Panaflex 16.

AVAILABLE ACCESSORIES: Many of the accessories listed for the Platinum Panaflex (see Section 4.29) can also be used with the Panaflex 16.

4.33 PHOTO SONICS 35-4B/4C

Ultra ultra high speed 35mm cameras capable of frame rates of up to 2500 fps. The only difference between the two models is the positioning of the film magazine.

MOVEMENT: Rotating prism, non-intermittent film transport mechanism in conjunction with a disk shutter to ensure even exposure. Image covers a full frame aperture.

SHUTTER: 72°.

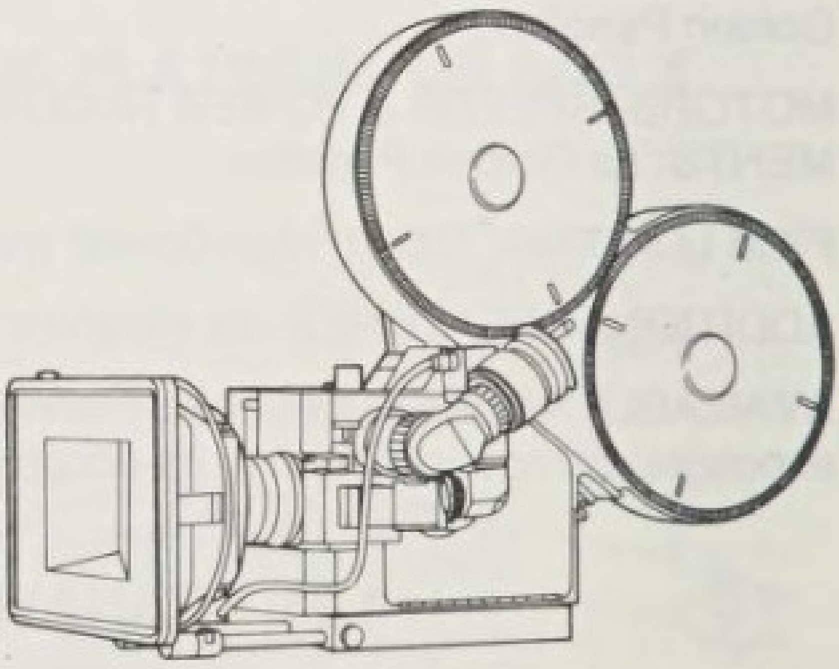


PHOTO SONICS 35-4C REFLEX

VIEWFINDER: Later models have a prism reflex system and utilize the Jurgens video-assist door and an Arri eyepiece. Non-reflex models have a side finder together with a reflex boresight viewfinder for focusing and line-up while the camera is stationary.

LENS MOUNTING: Reflex models have a Pentax 67 for lens mount Pentax 67 lenses. Non-reflex may have Photo Sonics, BNCR and Panavision. Lenses must have long back focal clearance.

MOTORS, SPEEDS & POWER REQUIREMENTS: Various single and three phase interchangeable AC motors available, some can achieve faster frame rates than others. Pre-set speeds up to 2500 fps, depending upon the motor. 208v AC three phase motor draws 60 amps per phase on run-up. Up to speed in 3 secs.

FILM LOADING: 500 or 1000 ft magazines. Dynamically balanced film cores required.

ADDITIONAL FEATURES: Facilities available for timing lights and fiducial marking, slit streak synchronizing with ballistic events, etc.

4.34 PHOTO SONICS 35-4E & ER

Ultra high speed, 360 fps, register pin cameras.

MOVEMENT: Twelve pull-down claws. Four register pins, vacuum gate.

SHUTTER: Adjustable while camera is stationary 120° – 5°.

VIEWFINDER: 4E is non-reflex with side viewfinder. Reflex finder for focusing and line-up usable only when camera stationery. Often used with an Angenieux 24 - 240mm reflex zoom lens. The later 4ER model has a beamsplitter reflex and uses a Jurgens video-assist door and Arri eyepiece.

LENS MOUNTING: Photo Sonics, BNCR or Panavision.

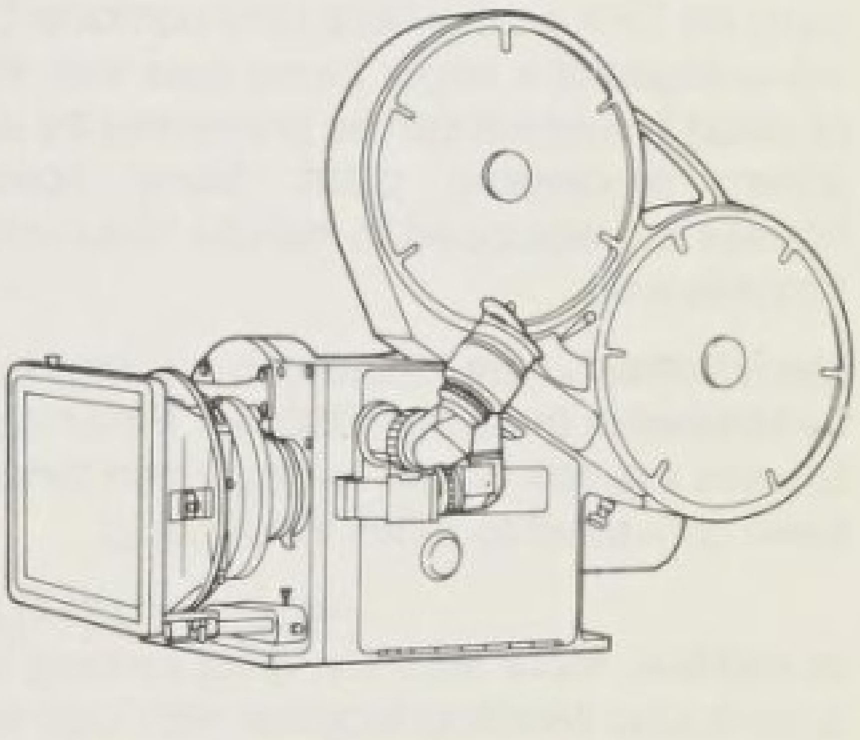


PHOTO SONICS 35-4ER

MOTORS, SPEEDS & POWER REQUIREMENTS: 220v AC to any pre-set speed (6 – 360 fps). Draws 30 amps on run-up. Up to speed in 3 secs. 24 fps override for slating purposes.
FILM LOADING: 1000ft displacement magazines.

ADDITIONAL FEATURES: Internal heaters, run-out switch, Arriflex matte-box compatibility

4.35 PHOTO SONICS ACTIONMASTER/500 & SPORTSMASTER/500

A range of 500 fps 16mm cameras much used for documentary, scientific and sports cinematography.

MOVEMENT: Double claw pull-down, two register pin movement incorporated into each film magazine.

SHUTTER: Later models are adjustable 160° – 7.5°. Earlier models have a 120° fixed opening shutter which may be replaced with smaller openings for specialized scientific work.

VIEWFINDER: Some models have a reflex viewing prism (requires extra 1/2 stop exposure) others are usually used with an Angenieux reflex zoom lens.

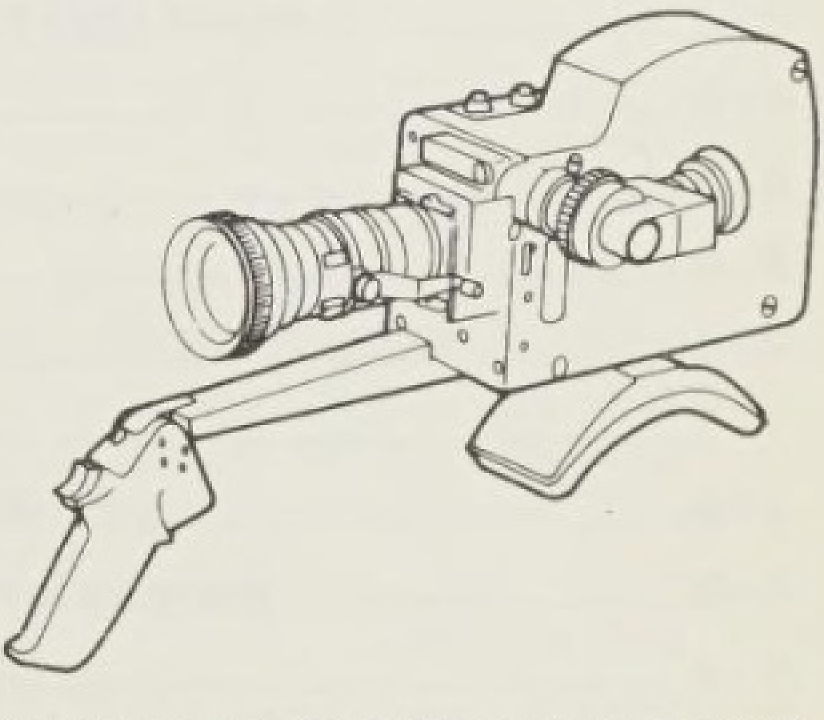


PHOTO SONICS ACTIONMASTER/500
1PDL

LENS MOUNTING: Usually Arri SB. Prism models have a limited back focal clearance. Non-reflex versions have a 'C' mount.

MOTORS, SPEEDS & POWER REQUIREMENTS: 28v DC is standard. Various AC and a crystal controlled (at 24 fps) are optional.

FILM LOADING: 200, 400 & 1200 ft co-axial magazines which incorporate the film pull-down mechanism clip onto the camera body. Film must usually be wound on daylight loading spools and be double row perforated. Split reels may be used if daylight loading stock is not available. Some examples use only long stroke (0.3000 in) perforated film.

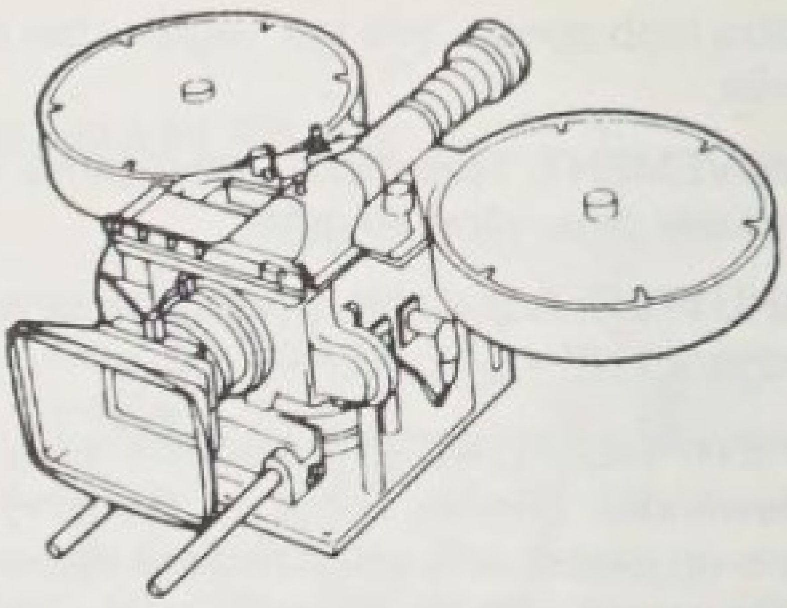
ADDITIONAL FEATURES: Behind-the-lens filtering.

AVAILABLE ACCESSORIES: Automatic exposure control, dual-speed pistol grip/shoulder mount, time lapse control, instrumentation and timing light systems for instrumentation filming, strobe sync & video assist.

4.36 VISTAVISION CAMERAS

Vistavision type cameras shoot with an 8 perforation horizontal format and are much used for SFX work where they combine the advantages of a larger frame area with that of using film which can be processed by any 35mm processing plant. Many optical houses are equipped to handle Vistavision process work.

Many butterfly type Vistavision cameras built by Mitchell in the early 1950s for Paramount Studios are still in use to-day, often having been converted to reflex viewfinding.



'BUTTERFLY' TYPE VISTAVISION CAMERA

In addition, more recently, quiet running Vistavision format cameras have been built for sync-sound shooting together with high-speed models for SFX work.

5 CAMERA MAINTENANCE

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Modern cameras require little day-to-day maintenance other than being kept scrupulously clean inside and out and the application of the correct amount of the correct oil in the correct places at the correct intervals.

This is particularly important on cameras running at 100fps or faster, which may require lubrication before every run.

Wipe exterior of camera clean and dry if it has been exposed to water or dust.

Brush away sand, dust, chips of film and snow from crevices. If using a blower of any kind be very careful not to blow the dirt further into the mechanism. The worst way to clean a camera is to blow any dust, grime, film chips and road grit further into the camera by using an aerosol air-spray.

Remove any marks from optical surfaces with cleaning solution and soft tissue, use a sable hair brush to remove dust.

Do not clean surfaces which are already clean; it can only cause damage. Do not blow on any steel surface with moist breath; it causes corrosion.

Small amounts of dust on a mirror shutter or inside or a lens or viewfinder optic are best left alone. Lubrication must be done exactly as recommended in the maker's handbook.

Cameras equipped for com-mag sound recording should be checked for dirt and emulsion build-up on the recording head. Fall-off in sound recording quality may also be due to poor film contact with the magnetic head, the heads in need of demagnetizing, over- or under-modulation, panning and/or tilting the camera sharply while recording, or the camera drive belt or the magazine take-up belt or clutch being set too tightly.

5.1 IN-FIELD MAINTENANCE

The following maintenance practices are recommended by the various camera manufacturers.

Camera technicians who plan shooting in circumstances where in-field maintenance will be necessary should take away with them all the correct tools and lubricants and a supply of cleaning materials. It must remembered that over-lubrication can sometimes do as much damage as under-lubrication and that excess oil may splash onto film if not wiped away.

AÄTON 16 & 35mm cameras: No lubrication required.

AGE IMAGE 300: Anderol L4010 oil to be applied to the movement bearings and linkages every 5000ft (150m) or once a month (whichever comes first). Jet Lube AP-5 Micromix grease to be applied to the right angle gear drive and to the mirror shutter drive gears every 1000ft (300m) of 300 fps running. The same grease should also be applied to the drive gear of each magazine every 30,000ft (10,000m).

ARRIFLEX IIC: One point on the pull-down mechanism to be oiled and two to be greased every 10,000ft. (6000m).

ARRIFLEX III: No lubrication required.

ARRIFLEX 35 BL I, II, & III: Two oil reservoirs in Mk.II & III movement camshafts (three in Mk1), which keep oil-wicks moist, to be refilled with oil and the four cam followers to be lightly brushed with oil every 60,000ft (20,000m). The magazine film guides should be checked for film chips and emulsion build-up and cleaned at frequent intervals.

ARRIFLEX BL 4 & 4s: Movement lubrication required only required every 300,000ft of exposed film. Periodically, the magazine lock, the pins of the magazine cover lock (3 each) and the corresponding parts of the magazine cover, the camera door lock and the tripod bush should all be very lightly greased. As with the earlier models, the magazine film guides should be checked for film chips and emulsion build-up and cleaned at frequent intervals.

ARRIFLEX 535: No lubrication required. The area between the pressure plate and the film gate and the magazine film guides should be checked for film chips and emulsion build-up and cleaned at frequent intervals.

ARRIFLEX 16 BL, M and St: Special oil pens required to depress steel balls which protect oil holes. Lubricate one point on 16 BL, two on M and two on St, plus three St rollers to be lightly oiled, every 30,000ft (10,000m).

ARRIFLEX 16SR: No lubrication required.

CINEMA PRODUCTS CP16: No lubrication required.

ECLAIR CM3: Six oil points in camera body and three places in magazines to be oiled at frequent intervals. Inch movement to oil both ends of pull-down linkage.

ECLAIR 16 NPR and ACL: No lubrication required.

MITCHELL BNCR and PANAVISION PSR: Film transport movement to be oiled daily (see diagram).

MITCHELL S35R Mk II: Film transport movement to be oiled daily at 24 fps and BEFORE EVERY TAKE at 100 – 120 fps (see diagram).

MOVIECAM: No lubrication required.

NAC E–10: Above 8000 fps lubricate with a NAC atomizer for one second every roll regardless of film capacity. Below 8000 fps lubricate with a NAC atomizer for one second every 800ft (see diagram).

PANAFLEX 65: Film transport movement to be oiled daily. (see Mitchell NC diagram)

PANAVISION 65 LIGHTWEIGHT & HIGH SPEED: Film transport movement to be oiled daily (see diagram).

PANAVISION PANAFLEX: Film transport movement to be oiled daily (see diagram). Pad at bottom of back plate to be kept moist with special silicone fluid. Check daily by lightly pressing the cover strip.

PANAVISION PANASTAR: Film transport movement to be oiled daily (see diagram).

PANAVISION PSR: Film transport movement to be oiled daily (see Mitchell NC diagram).

PANAFLEX 16: Film transport movement to be oiled daily (see diagram).

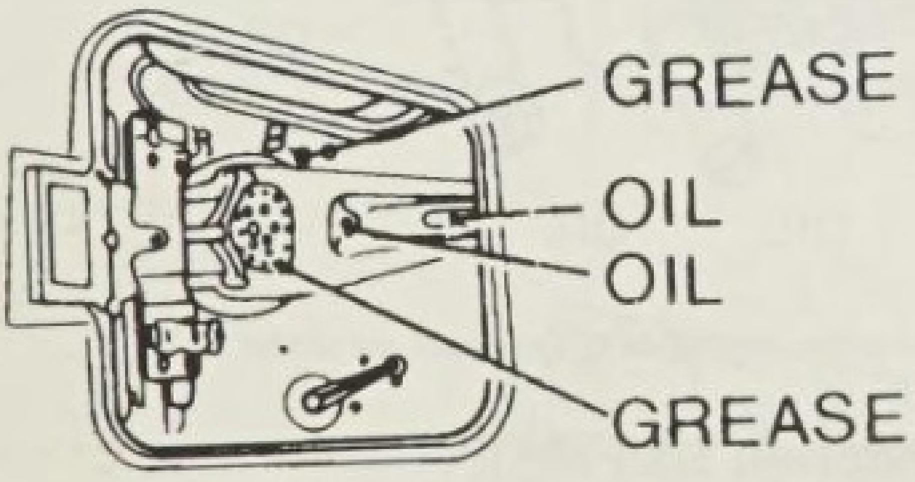
PHOTOSONICS 35MM 4E: At 6 – 60 fps registration pins and slides of movement to be lubricated every 5000ft, at 60 – 180 fps every 2000ft. and at 180 – 360 fps every 1250ft. Only correct oils to be used. Two felt pads located behind upper roller to be kept moist with silicone fluid and all gearing, especially bevel miter gears, to be checked every 5000ft. Interior of camera to be cleaned thoroughly after each take (see diagram).

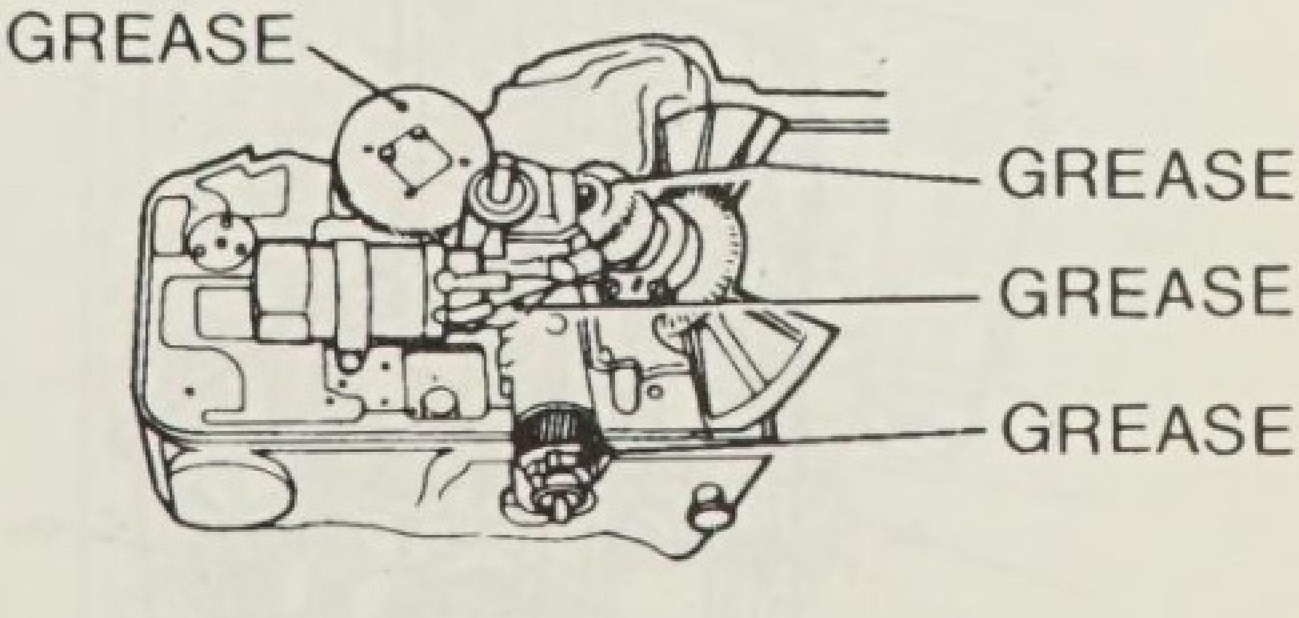
PHOTOSONICS 4B/C: Lubricate drive gears with AP-5 grease every 10,000ft. Access to gears is obtained by removing the rear panel of the camera.

PHOTOSONICS 16MM 1PD: At high speeds eccentric pin, register pins and bushings to be oiled every 1200ft (400m) (see diagram).

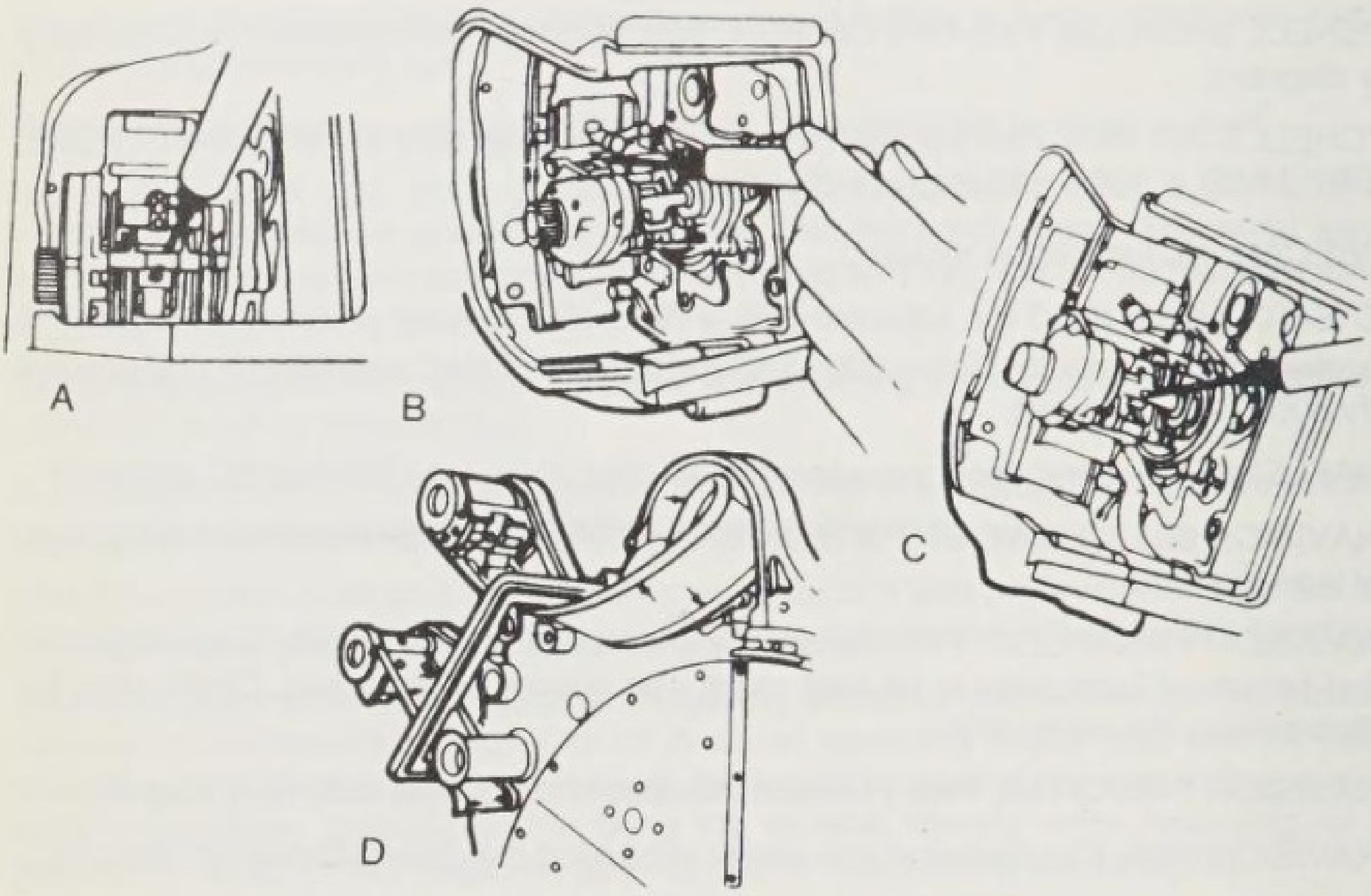
5.2 CAMERA LUBRICATION DIAGRAMS

5.2.1 Arriflex IIC



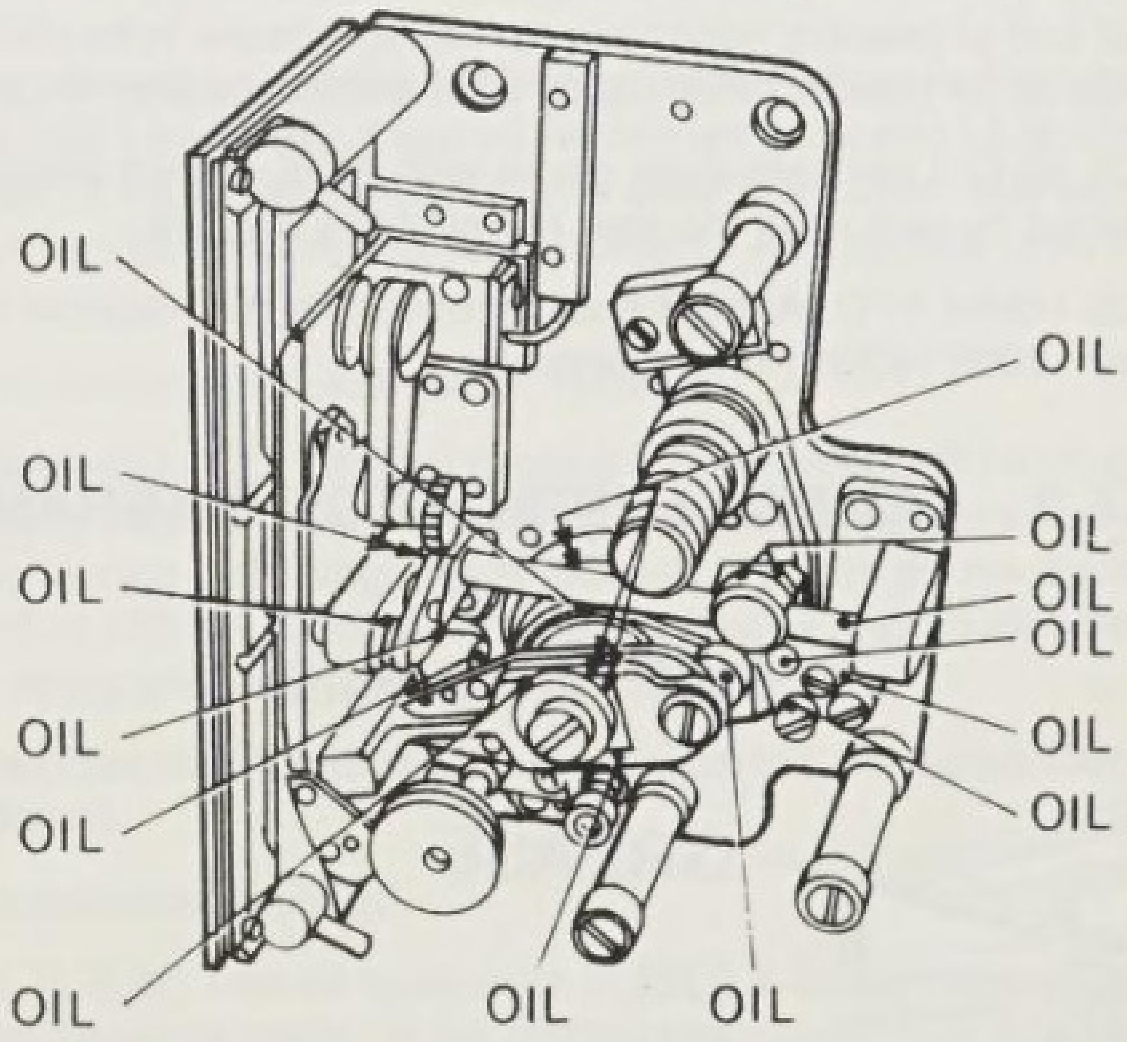


5.2.2 Arriflex 35BL



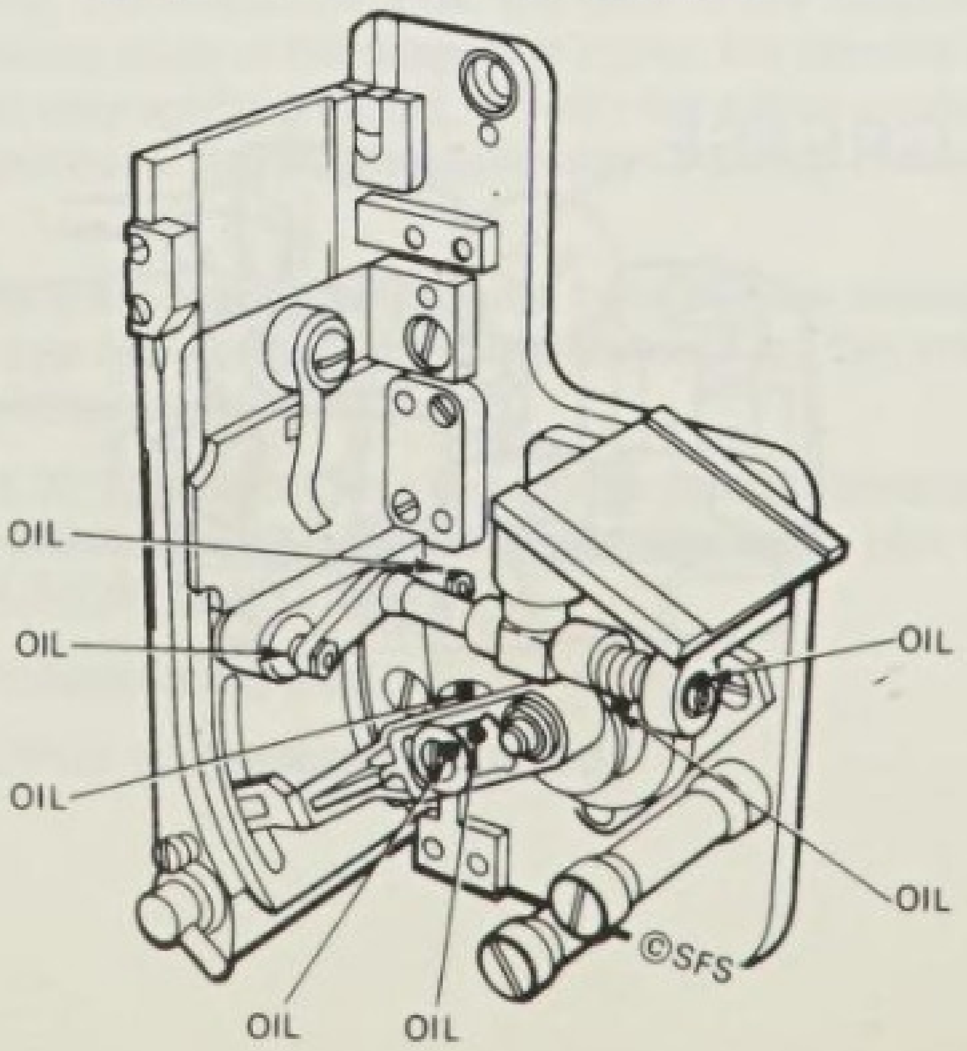
A. Mk I only, B & C. Mk I & II only (to be oiled with a special oil syringe as shown)
D. Magazine film guide covers to be removed and cleared of film chips (all models)

5.2.3 Mitchell NC series, Panavision PSR, etc.

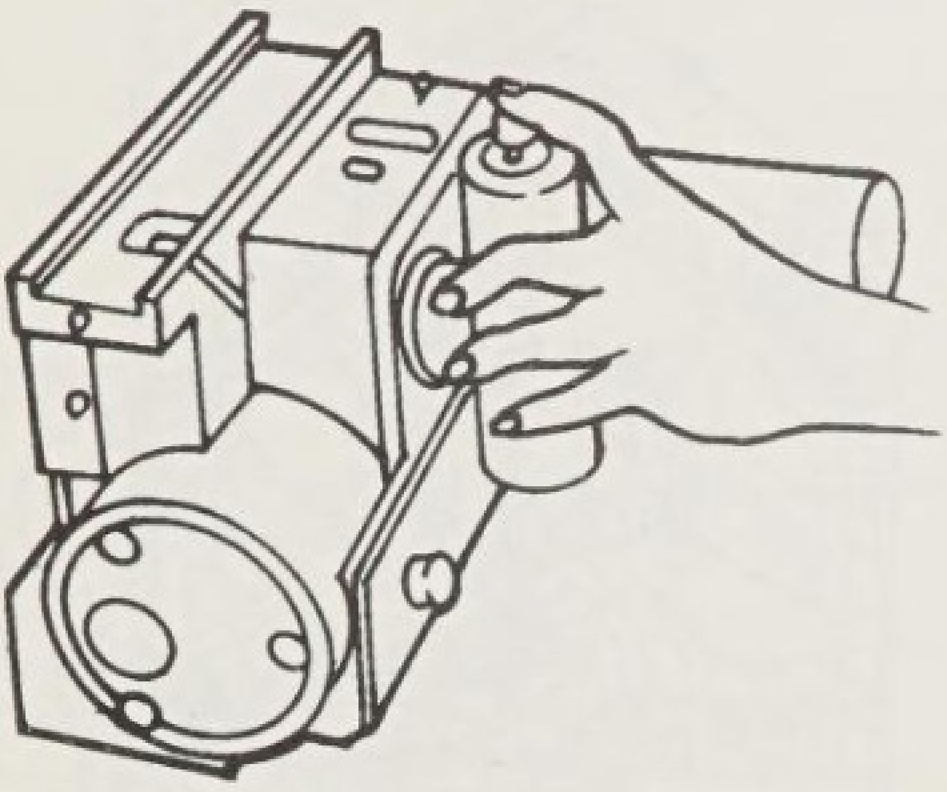


Various 65mm cameras based on the Mitchell BFC movement are similar

5.2.4 Mitchell S35 MKII

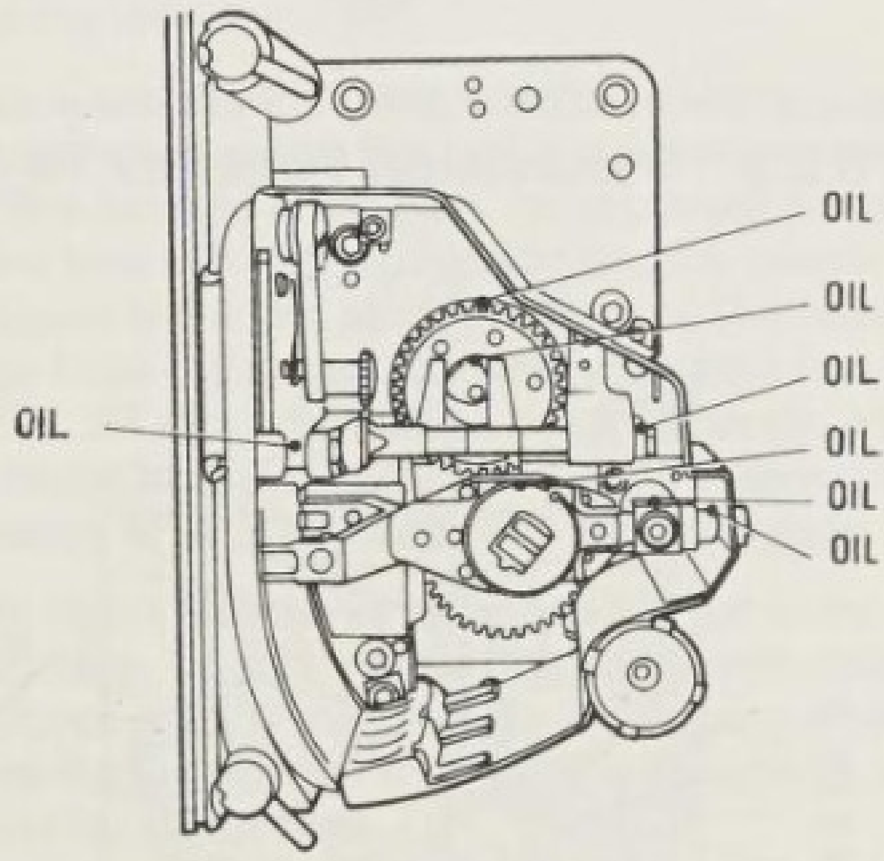


5.2.5 NAC E-10

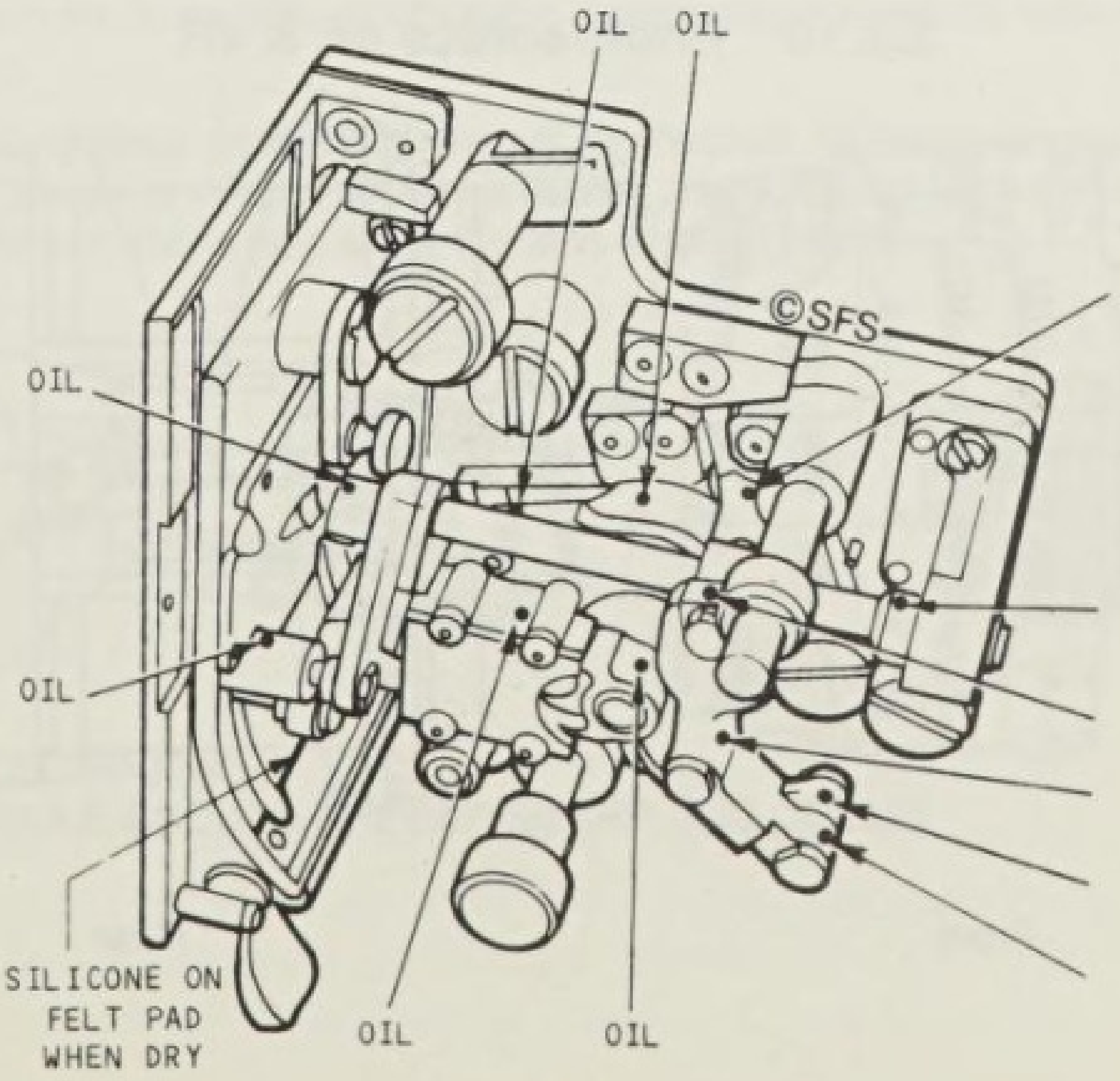


Apply aerosol lubricant for 1 second

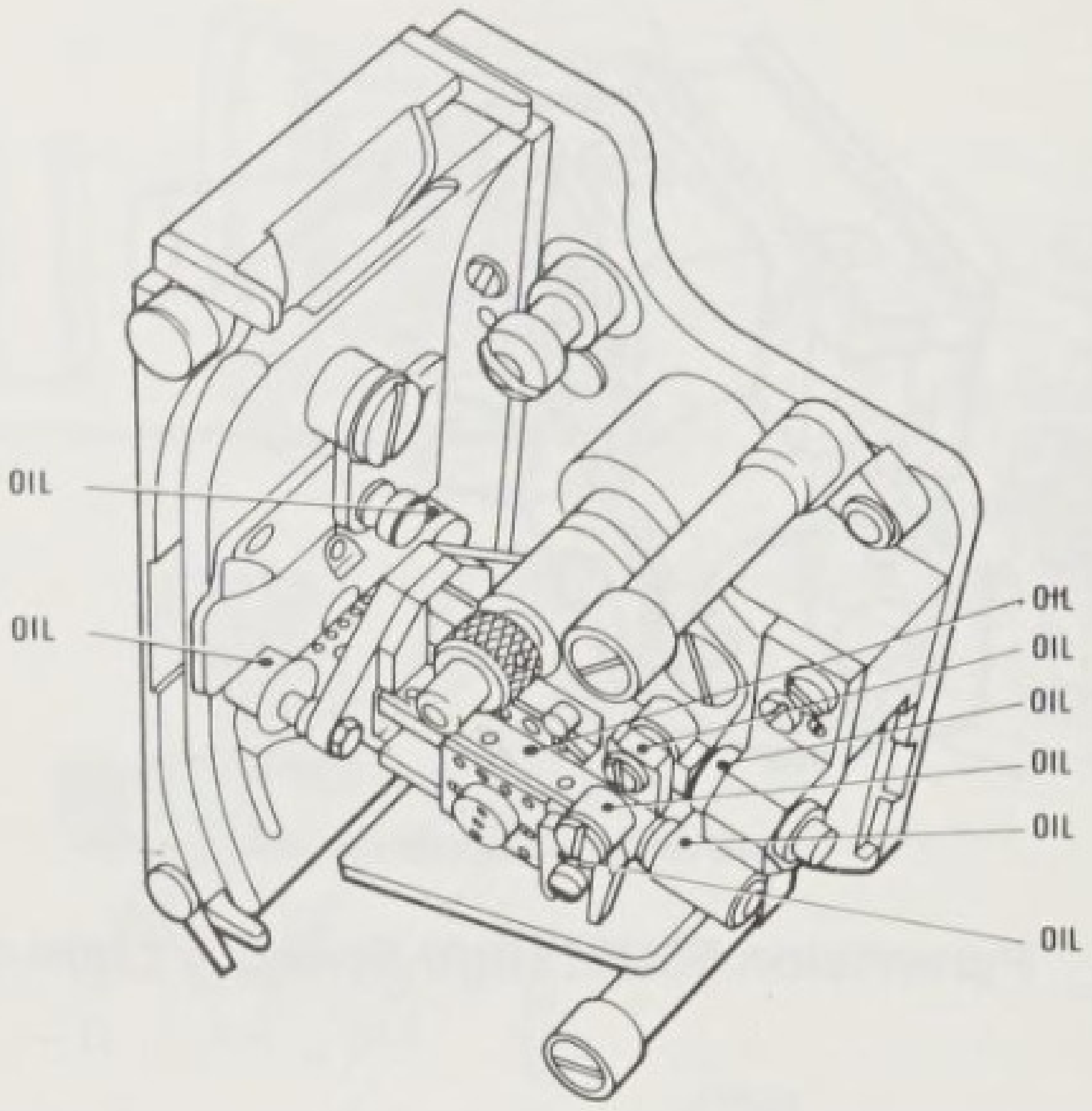
5.2.6 Panavision 65MM High-Speed & Light-Weight



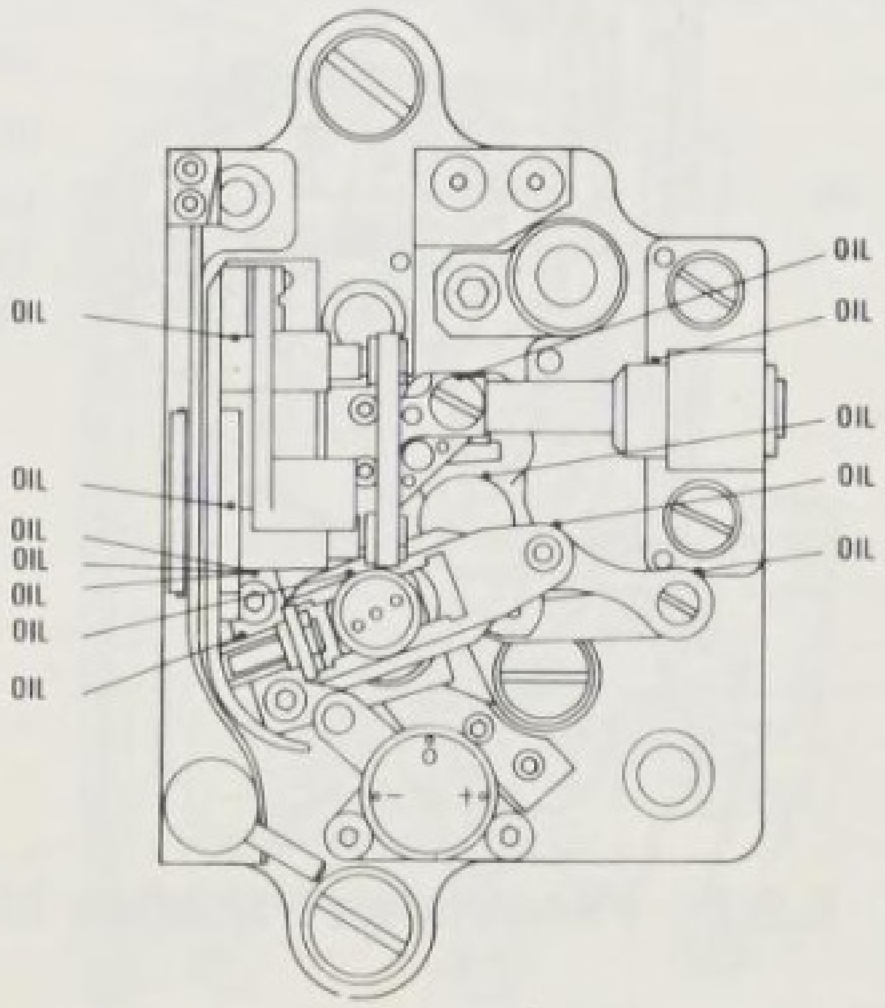
5.2.7 Panavision Panaflex 35



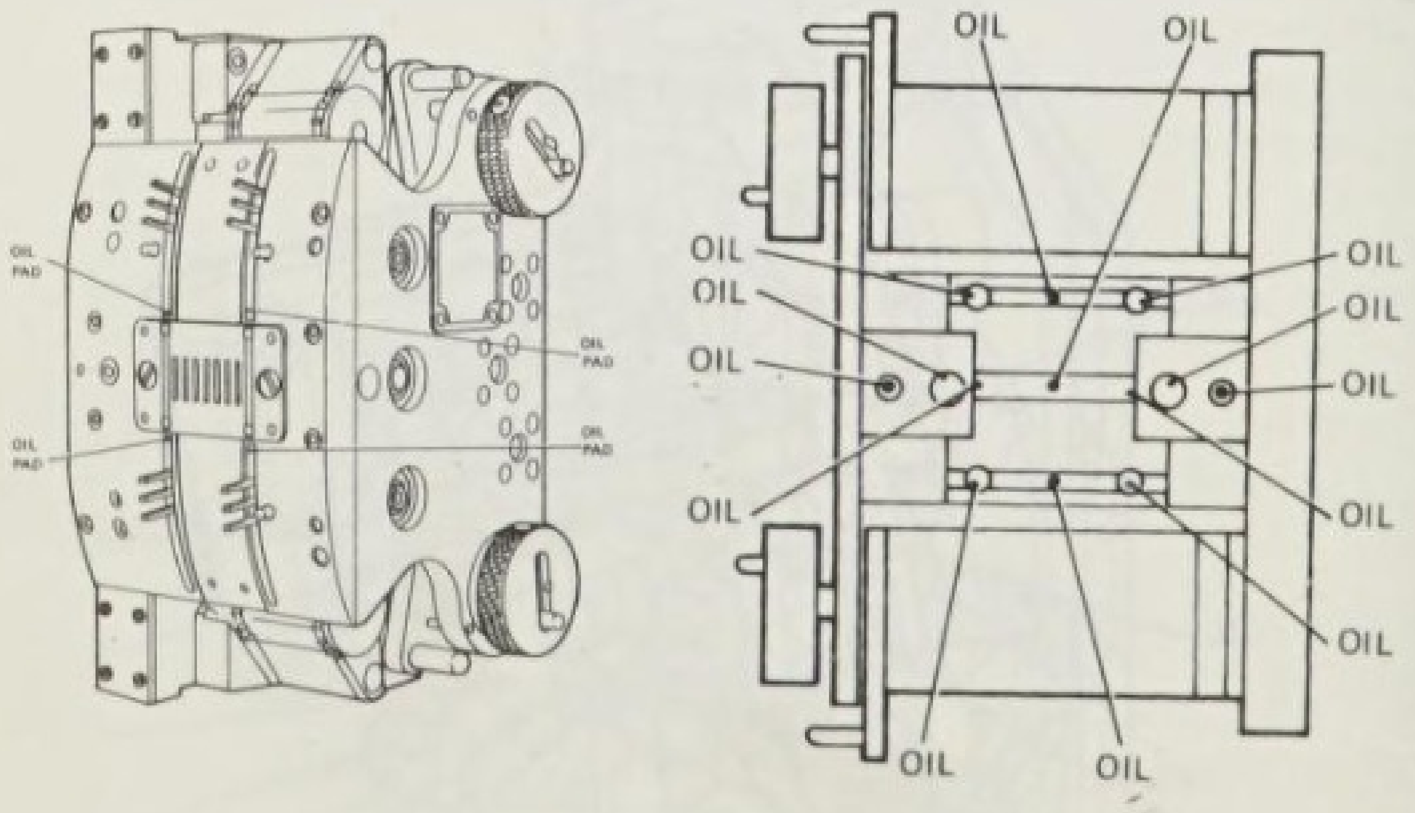
5.2.8 Panavision Panastar



5.2.9 Panavision Panaflex 16



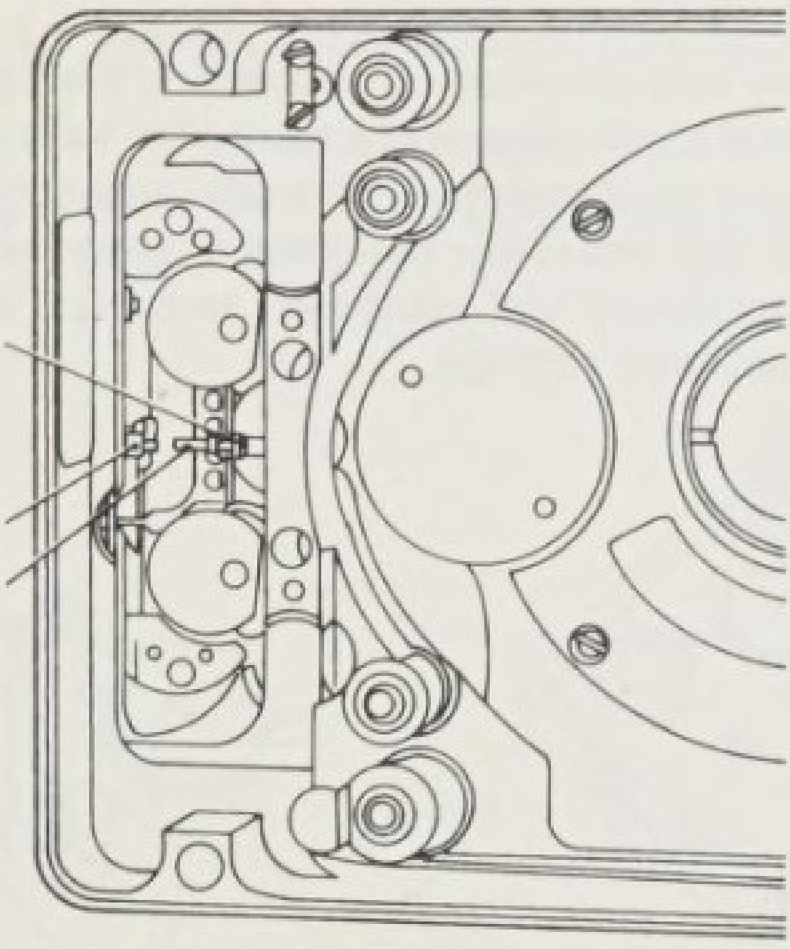
5.2.10 Photosonics 4E & 4R



Front

Rear

5.2.11 Photosonics 16mm 1PDL



5.3 FLANGE FOCAL DEPTH SETTINGS

The distance from the face of lens mount to the back of the aperture plate must be accurately set to within a tolerance of 0.0001" (0.0025mm) at normal room temperature. This can only be done by replacing the film with a flat plate and using a highly accurate depth gage to measure the distance.

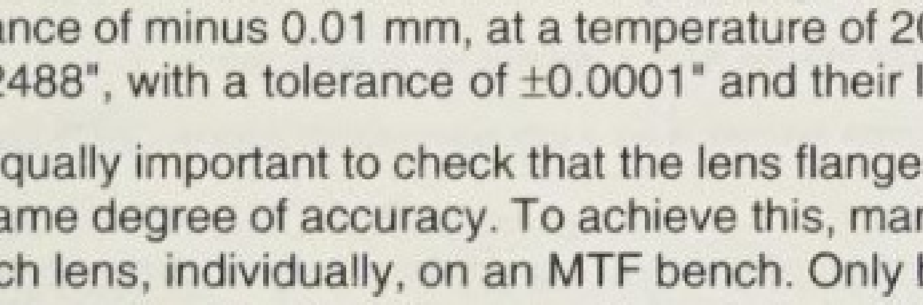
To achieve optimum focus and depth of field, combined with a gutsy image, and to make allowance for any air gap between the film and the aperture plate during the exposure period and any lack of film flatness in the gate, most current camera manufacturers and rental companies set the lens mount flange focal distance deeper than the front surface of the photo sensitive layers of the film stock and into the film base. Arnold & Richter, for instance, set the flange focal distances of Arriflex cameras to a nominal value (which varies between 52 and 51.97 mm depending upon the camera model) with a maximum tolerance of minus 0.01 mm, at a temperature of 20°C. Panavision set their flange depth to 2.2488", with a tolerance of ±0.0001" and their lens mounts to 2.2500".

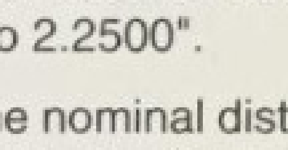
It is equally important to check that the lens flanges are set to the nominal distance with the same degree of accuracy. To achieve this, manufacturers make the final adjustment to each lens, individually, on an MTF bench. Only by keeping a very tight control of both the camera and the lens flange settings is it possible to achieve complete interchangeability between all lenses on all cameras.

The infinity settings of lenses can be checked by placing a lens on a steel gage ring set on a flat surface and examining it with the aid of a collimator. The depth of the gage ring is very accurately ground and will take into account the recommended minus tolerance. The combined effect of camera flange focal depth and lens flange settings, *to the surface of the film,* can also be checked using an auto-collimator. This may not be the manufacturer's optimum which is usually a minus setting.

It may also be necessary to check that the film lies flat in the gate as it runs through the camera. This can be done with a collimator, comparing the results between stationary and running film.

The camera ground glass distance can be set, or checked, by fitting a lens which is known to have a good image at infinity, usually a 50mm, and using an auto-collimator to check that it gives optimum sharpness when the lens is set at infinity.

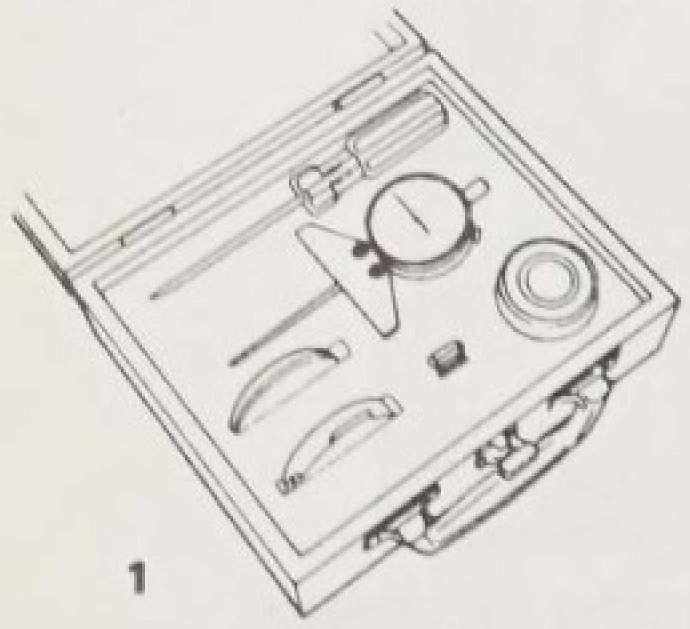




1. USING A COLLIMATOR;
2. THE GRATICULE SHOULD APPEAR SHARP AND CLEAR.

5.3.1 Checking the flange focal depth of a camera

As already noted, the only accurate method of checking the flange focal depth setting of a camera is by the use of a depth gage and a steel plate held against the aperture plate in place of the film. Camera equipment suppliers can usually supply a flange focal depth gage for use on location and whenever the going is expected to be rough it is a wise precaution to take the necessary test equipment to ensure that the camera and lens interface remains at its optimum settings.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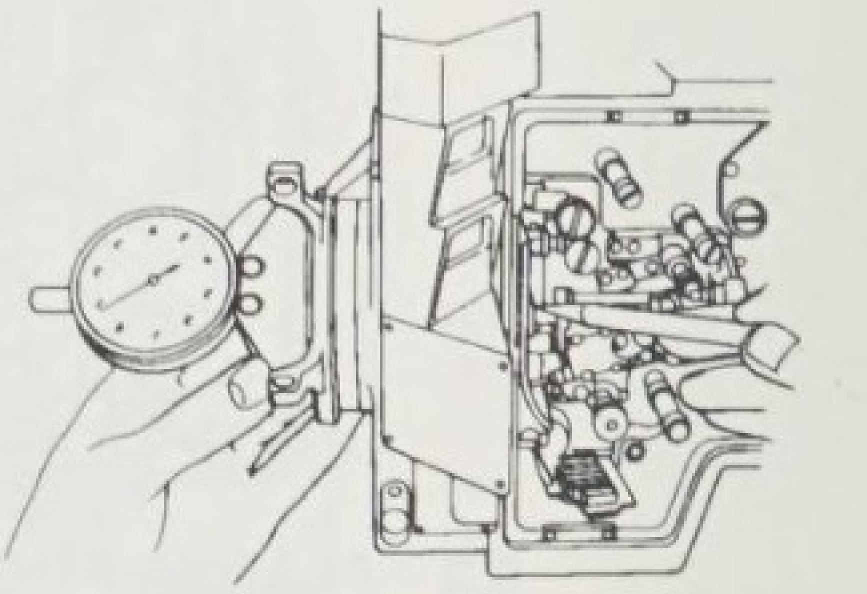
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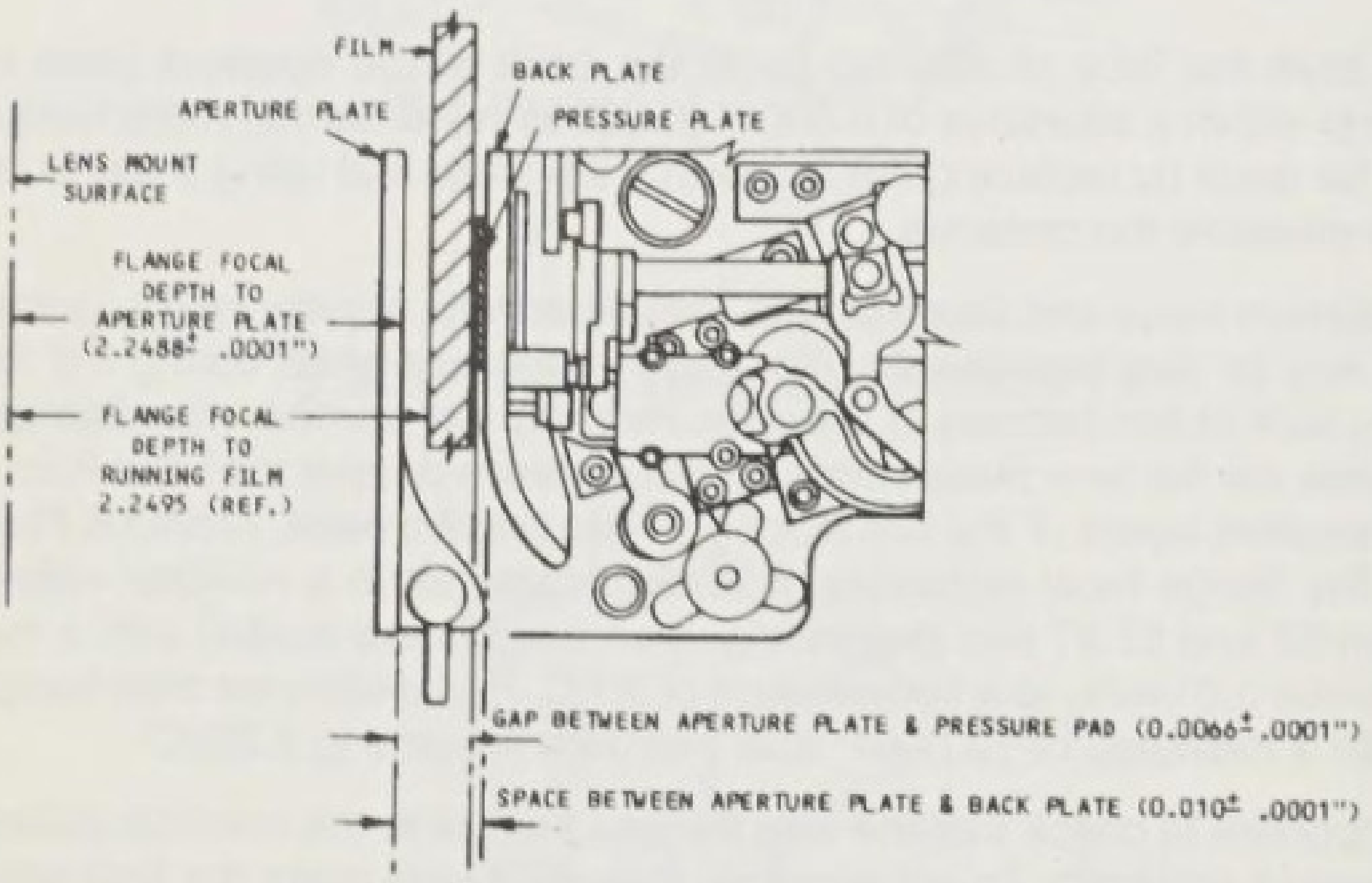
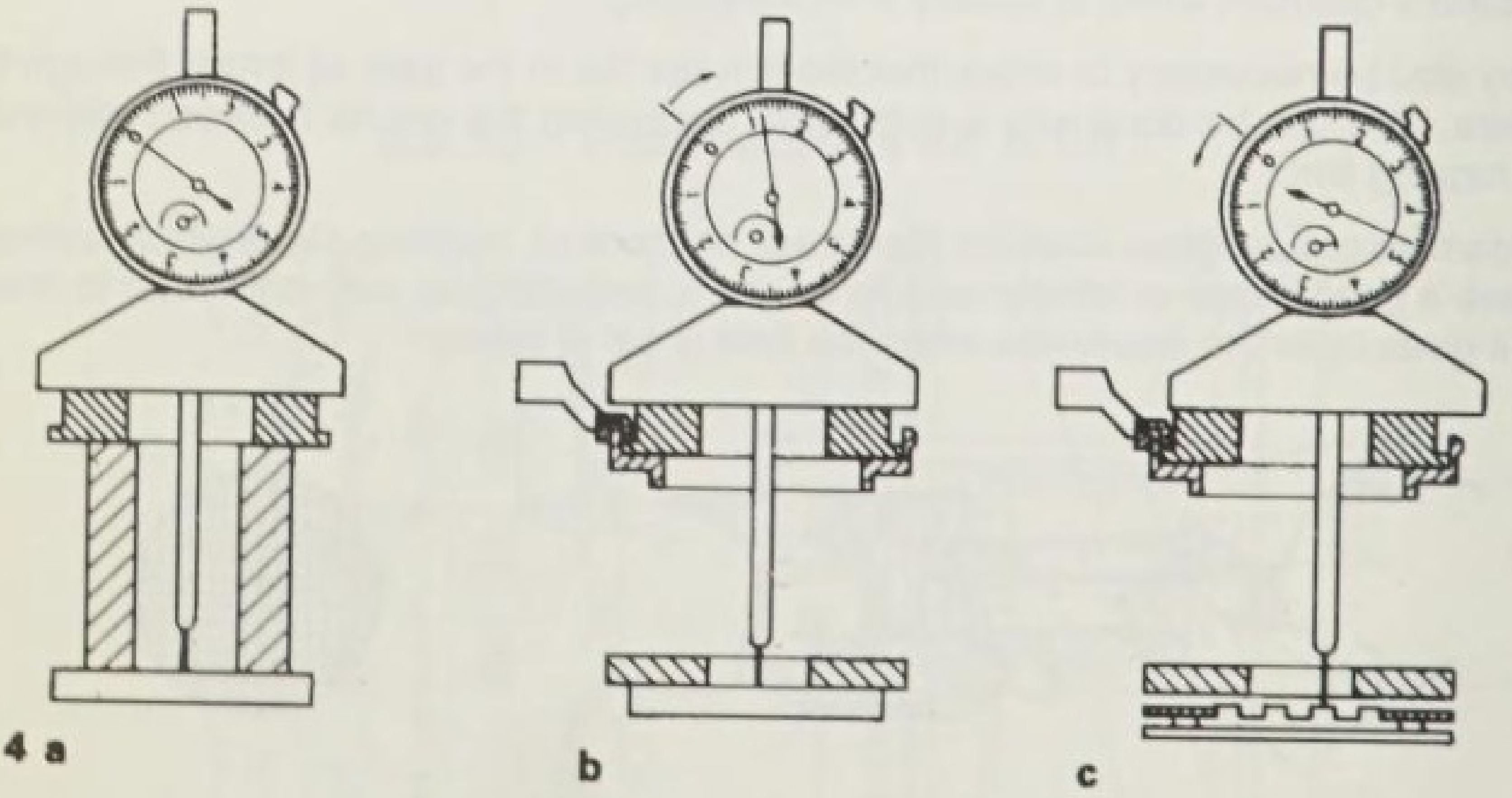

FILM
APERTURE PLATE
BACK PLATE
PRESSURE PLATE
LENS MOUNT SURFACE
FLANGE FOCAL DEPTH TO APERTURE PLATE (2.2488± .0001")
FLANGE FOCAL DEPTH TO RUNNING FILM 2.2495 (REF.)
GAP BETWEEN APERTURE PLATE & PRESSURE PAD (0.0066±.0001")
SPACE BETWEEN APERTURE PLATE & BACK PLATE (0.010± .0001")
3

1. Flange focal depth gage set; 2. Method of using a flange focal depth gage on a Panaflex camera (note use of a pencil to hold the gage plate in position behind the aperture plate); 3. Critical lens/film/camera distances.

In addition to checking the distance from the lens mounting flange to the surface of the film it is also necessary to measure and check the distance between the aperture plate and the film pressure pad – the gap wherein the film runs.



Flange focal depth setting procedure: a. Set the dial gage to zero with the aid of a 2.2500" gage block, plate and adaptor flange; b. With a gage plate behind the aperture, and using the adaptor flange, check the flange focal depth of the camera. It should read -0012" ±.0001 on the dial; c. Check the depth of two center rails of the pressure plate. They should register +.0054" on the dial.

5.4 LENS MOUNTING STANDARDS

Camera	Flange focal depth			
	Nominal in.	Tolerance in.	Nominal mm	Tolerance mm
Aäton Super 16			40.00	${}^{-0.008}_{-0.017}$
Aäton 35			40.00	${}^{-0.040}_{-0.060}$
Arriflex, early cameras			51.985	${}^{+0.0}_{-0.01}$
Arriflex 16 SR			52.00	${}^{+0.0}_{-0.01}$
Arriflex, 16 SR-HS			51.97	${}^{+0.0}_{-0.01}$
Arriflex 35 BL			51.98	${}^{+0.0}_{-0.01}$
Arriflex 35 III			51.985	${}^{+0.0}_{-0.01}$
Arriflex lenses and ground glass, all cameras			52.00	${}^{+0.0}_{-0.01}$
Bolex 'C' Mount (prism camera)*			20.76	(17.52)
Bolex Bayonet (prism camera)*			26.46	(17.52)
Cinema Products	1.500			
'C' Mount	0.690		17.526	
'D' Mount	0.484		12.29	
Eclair			48.00	
Mitchell BNC & BNCR (nominal)	2.420			
Mitchell BNC & BNCR (recommended)	2.4188	±0.0001		
Mitchell S35	2.250			
Mitchell 16.	0.900			
Mitchell SPR*	2.424			
Mitchell NC	1.695			
Panavision camera flange focal depth	2.2488	±0.0001		
Panavision lens mounts and ground glass	2.250			
Photo-Sonics 4B/C, reflex (Pentax 67 mount)	3.346	±0.0005	61.44	±0.012
Photo-Sonics 4B/C, non-reflex (Nikon mount)	1.8297	±0.0005	46.47	±0.012
Photo-Sonics 4ER, reflex (BNCR mount)	2.419	±0.0005	61.44	±0.012
Photo-Sonics 4ER, reflex (Panavision mount)	2.249	±0.0005	57.12	±0.012
Photo-Sonics 4ML, (Nikon mount)	1,8297	±0.0005	46.47	±0.012
Photo-Sonics 1PDL, reflex, (Arri SB mount)	2.047	±0.0005	51.99	±0.012
Photo-Sonics 1PDL, non-reflex, (C mount)	0.6895	±0.0008	17.50	±0.017

*These are actual distances. The optical distance, after allowing for the effect of reflex prism or pellicle, is given in parentheses.
** To the face of the prism block. The optical distance is given in parentheses.

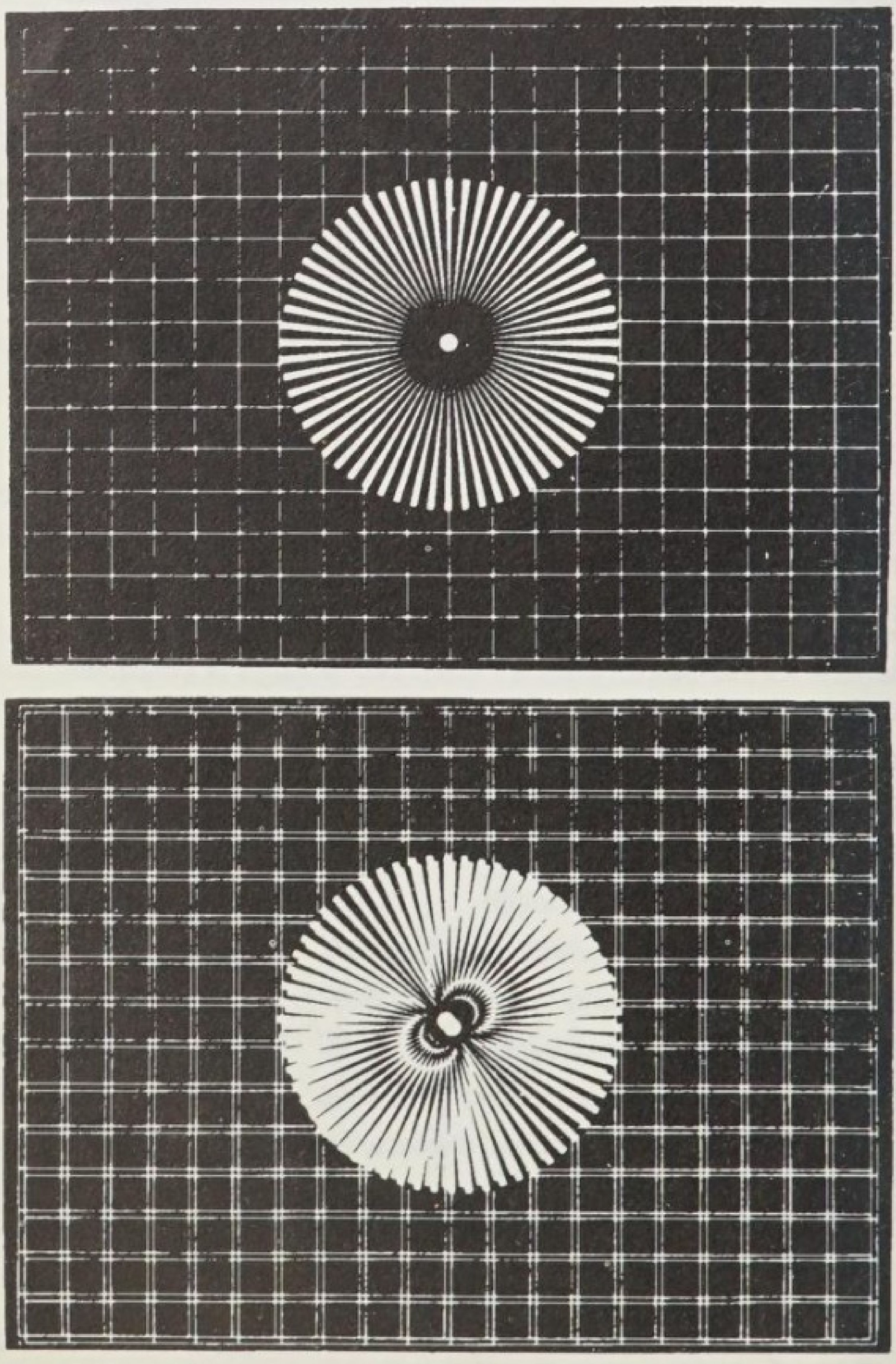
5.5 SHOOTING STEADINESS TESTS

To shoot camera steadiness tests on every camera to be used on a particular production is one of the most important pre-production tasks, especially if the production includes any scenes which involve composite work of any kind (see Section 7).

An effective method of shooting steadiness tests is to photograph a test chart, consisting of a grid of horizontal and vertical lines with a 'Siemens Star' pattern of radiating lines in the center of it, twice over, displacing the camera diagonally between takes.

The camera must be set on a particularly rigid support and loaded with filmstock to be used on the production. When threaded with film the frame in the gate must be marked so that it can be rethreaded a second time in exactly the same position. The test chart is photographed once, the film is rewound, rethreaded, the camera slightly realigned both to one side and slightly higher or lower, and the test chart is photographed again.

When projected, any general unsteadiness due to malfunctioning of the film registration system or incompatible film perforations, etc., will show as a moiré pattern in the Siemens Star and as movement between the pairs of lines. Any unsteadiness due to the shutter being even slightly open while the film is being pulled down will show as a blurred movement betwen pairs of lines on one edge of the frame, depending on which way the shutter rotates and covers and uncovers the film.



1. TYPICAL CAMERA STEADINESS TEST CHART; 2. RESULT OF DOUBLE EXPOSURE AND MOVING THE CAMERA DIAGONALLY BETWEEN TAKES. Note the moiré effect on the center pattern.

5.6 WINTERIZATION

When a camera is going to be used in VERY VERY COLD conditions it is advisable to ask the camera supplier to winterize the camera before going away.

Just below freezing point treatment with freshly applied 'wide temperature range' greases and the use of internal heaters, where fitted, or external heater barneys may be sufficient but if the temperature is likely to be below –10°F (–23°C), cameras will need to have a low temperature lubricant introduced.

If a choice of cameras is available it is better to choose one with bearings that are well worn and free running.

Transistors that will operate in very cold conditions may be required to replace those normally fitted in the electronic motor speed control system.

After extensive winterization a camera may become noisy and as much time and money will have to be spent in restoration after the assignment as was spent on preparation.

Below –40°F or °C a nickel cadmium battery will produce only 40% of its rated capacity. To keep them operating efficiently batteries should be kept warm by the use of battery belts worn by the camera crew during the day and taking them to bed with them at night. Batteries of higher voltage and greater capacity than normal should be used.

When not in use cameras, camera parts and lenses, etc. should be kept in plastic bags. Dustbin liners are ideal.

If it is likely to be extremely cold, rubber battery to camera cables become very brittle and should be replaced with neoprene.

To ensure that no part of the human body comes into contact with any metal part of the camera the eyepiece cup should be covered with chamois leather and a chamois leather barrier attached to the side of the camera to prevent it being touched by the operator's cheek.

Silk gloves should be worn during reloading and heavy gloves when handling equipment.

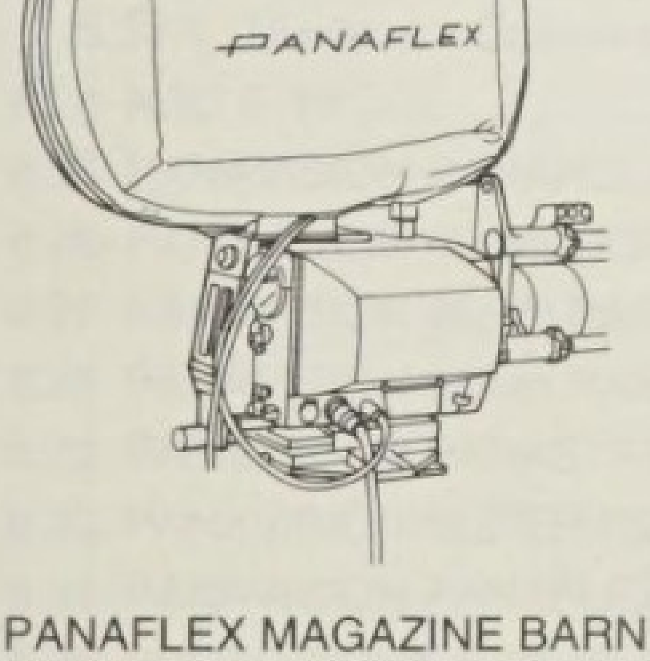
There comes a point when it is so cold that the only practicable camera to use is one driven by a clockwork motor.

If in doubt about the capability of a camera to operate under sub-zero conditions, a deep freeze may be used for test purposes. The camera should be placed in a polythene bag, to contain the condensation, and left in the freezer for 24 hours. When removed it should first be run without film and if all appears to be well, tested in its full operational mode. The use of a strobe light tester will reveal any uneven running.

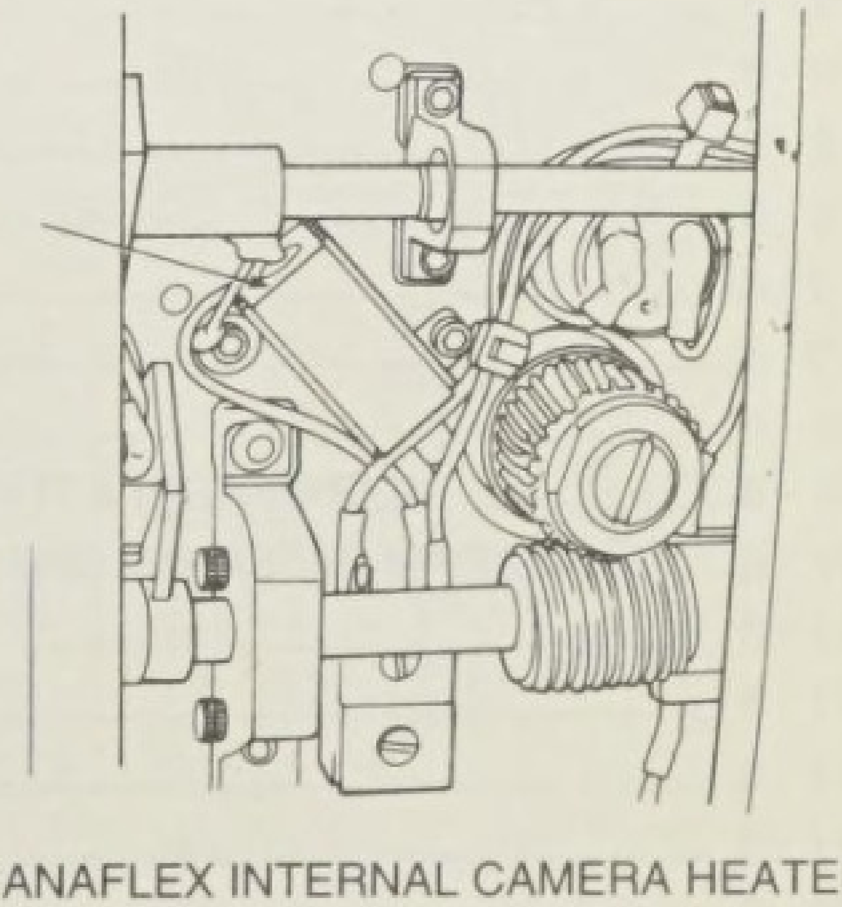
Avoid sudden changes in temperature.

While a warm camera may be taken into a cold situation and used without problems a cold camera cannot be used in the warm without severe misting up, particularly the lens and viewfinder.

Warming up a camera and lenses without condensation may be speeded up by placing them in a plastic bag during the process.



1. PANAFLEX MAGAZINE BARNEY



2. PANAFLEX INTERNAL CAMERA HEATER

6 CAMERA THREADING DIAGRAMS

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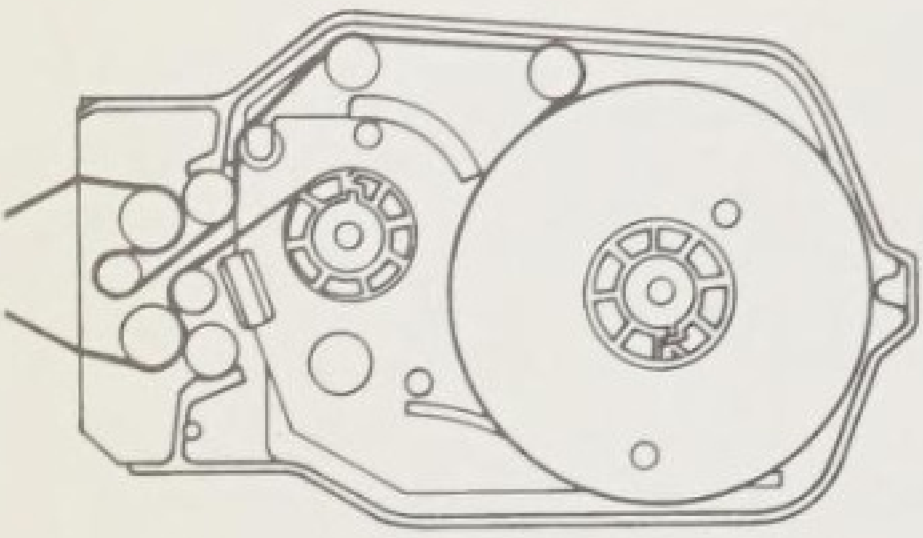
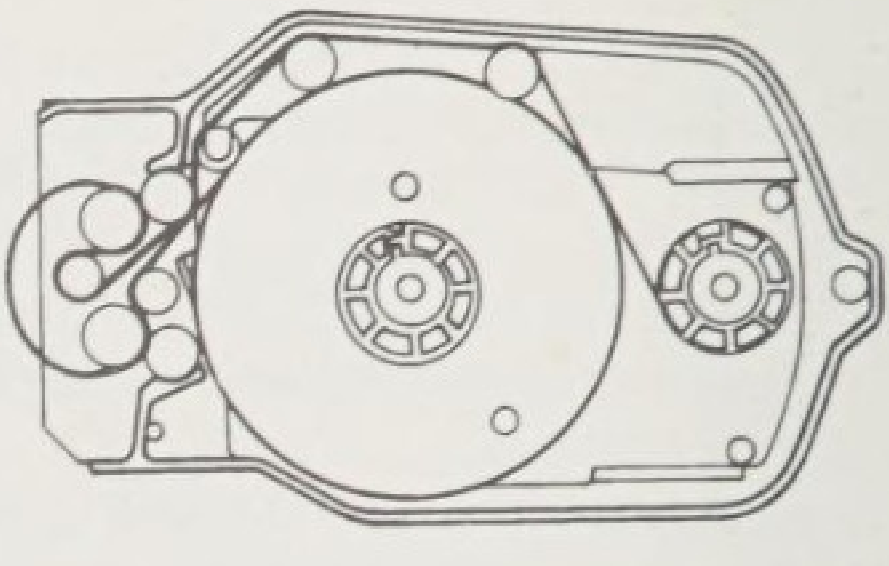
6.1 AÄTON 35



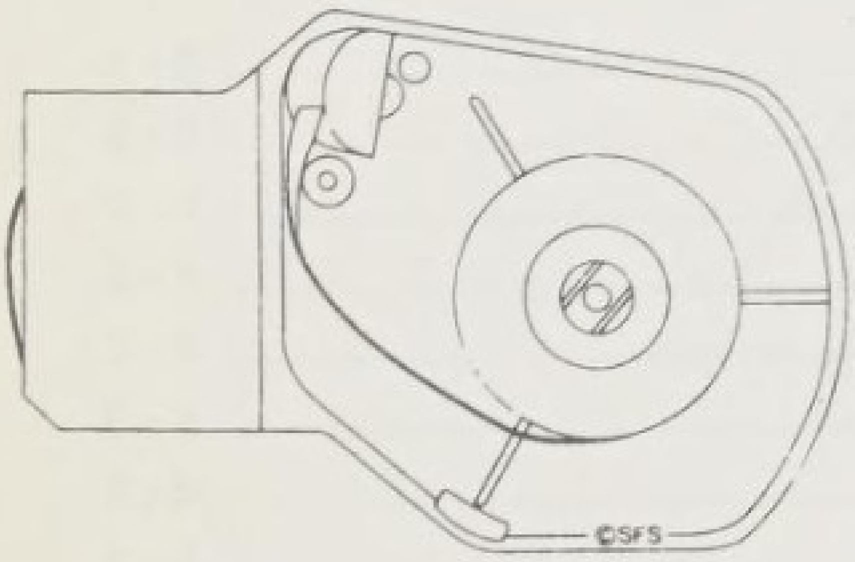
Position of film before exposure

Form 24 - 25 hole loop by placing 2" filmcore between front of magazine and film while lacing and make equal top and bottom loops



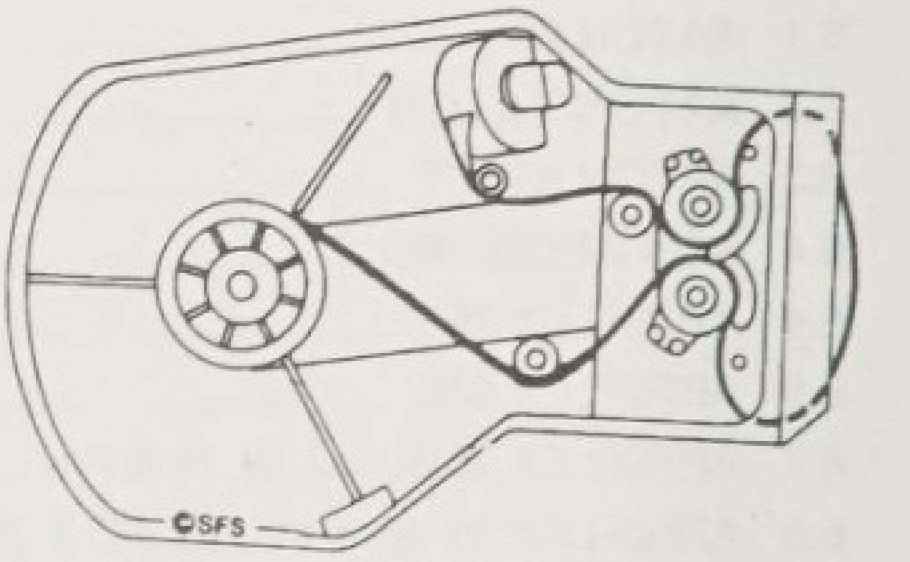
Position of film after exposure
Film takes up emulsion in

6.2 AÄTON 7 & LTR



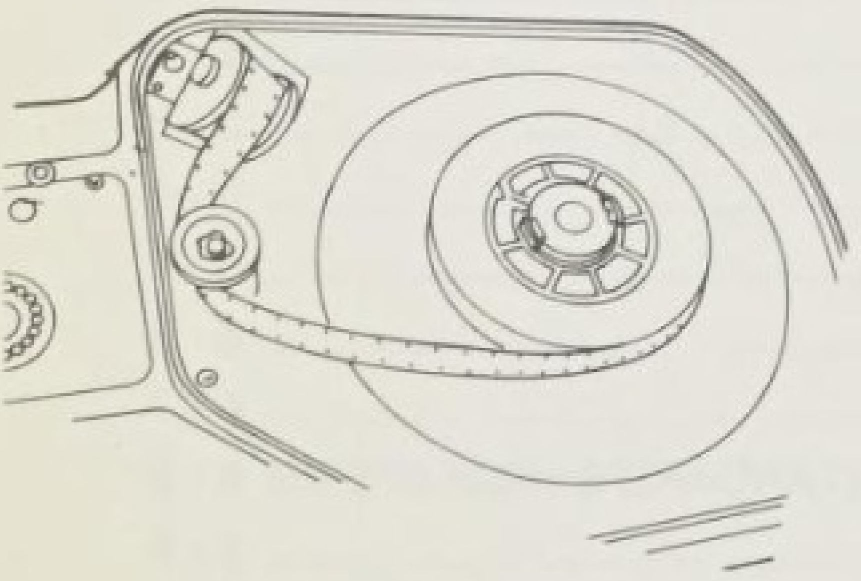
Supply side

Form 14 - 16 hole loop by holding two fingers sideways at top front of magazine while lacing and make equal top and bottom loops



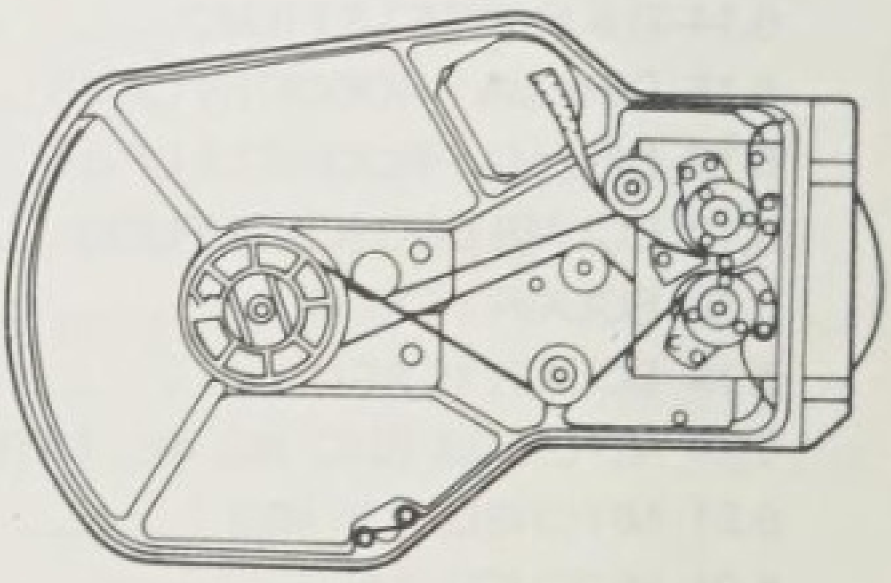
Take-up side
Film takes up emulsion in

6.3 AÄTON XTR^{plus}



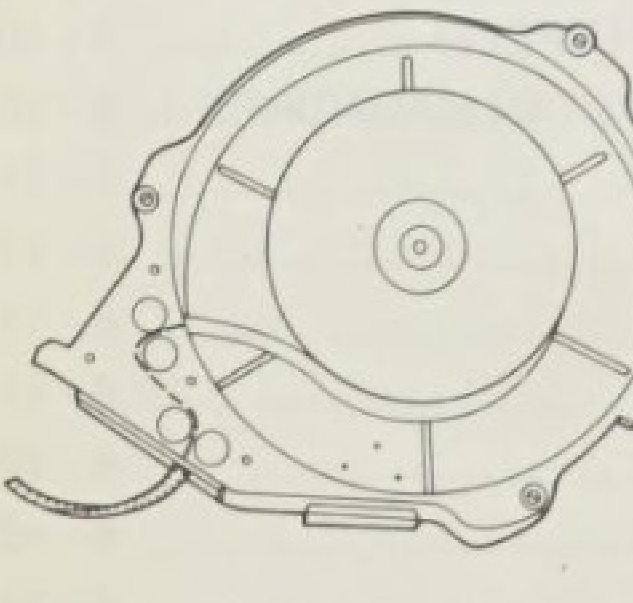
Supply side

Form 14 - 16 hole loop by holding two fingers sideways at top front of magazine while lacing and make equal top and bottom loops

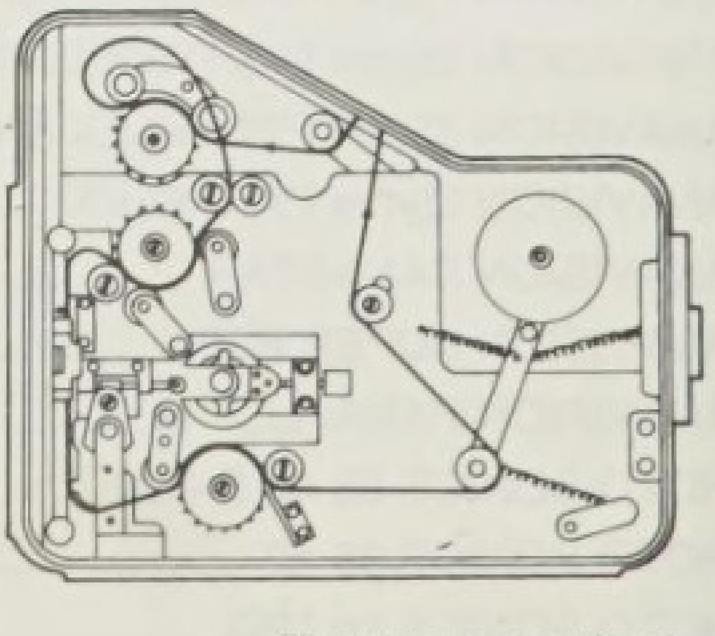


Take-up side
Film takes up emulsion in

6.4 AGE IMAGE 300

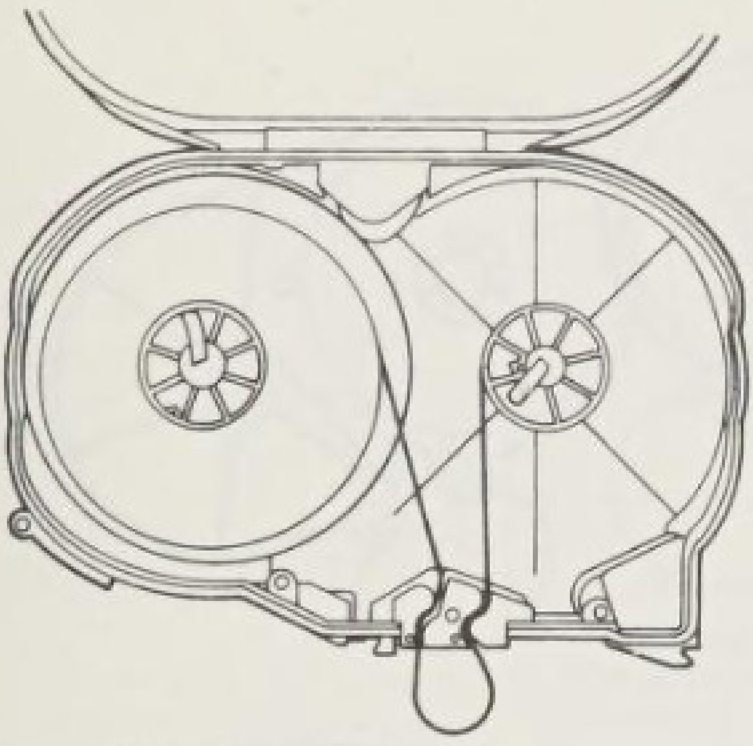


Supply side magazine

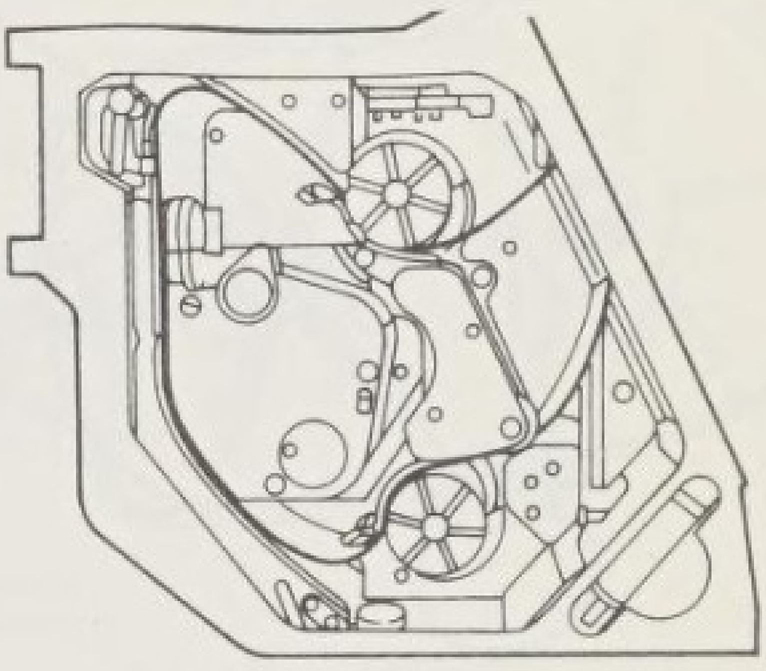


Film takes up emulsion in

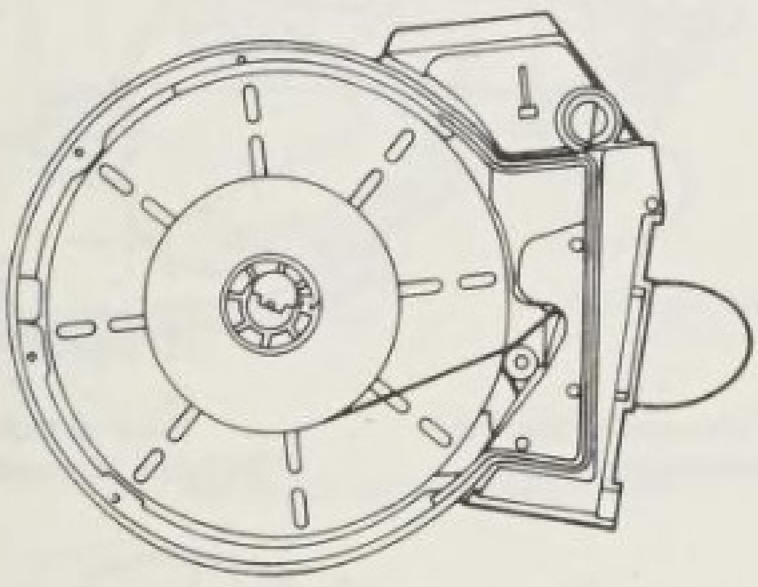
6.5 ARRIFLEX 765



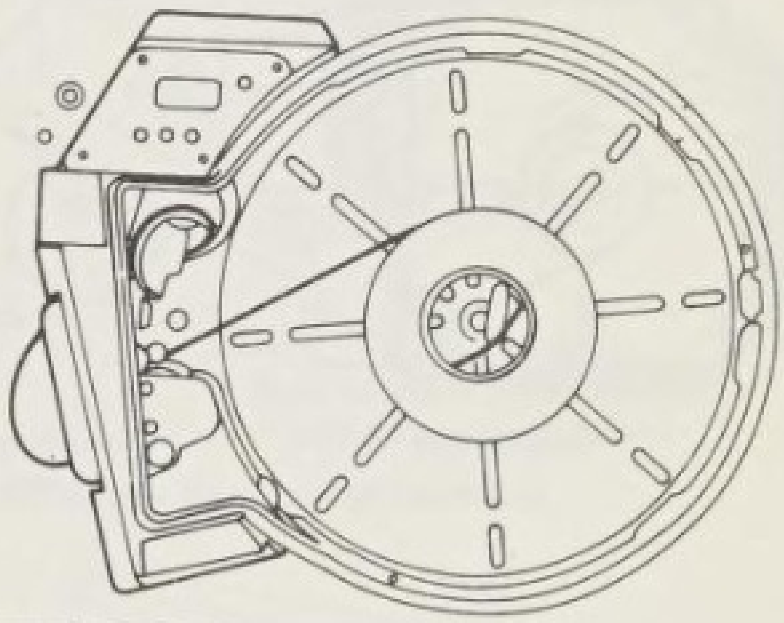
Film takes up emulsion in



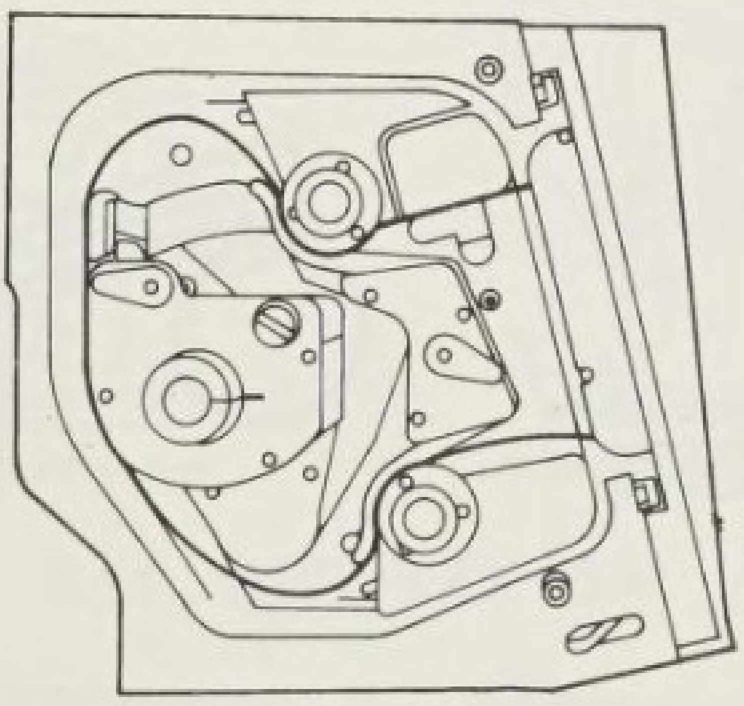
6.6 ARRIFLEX 535



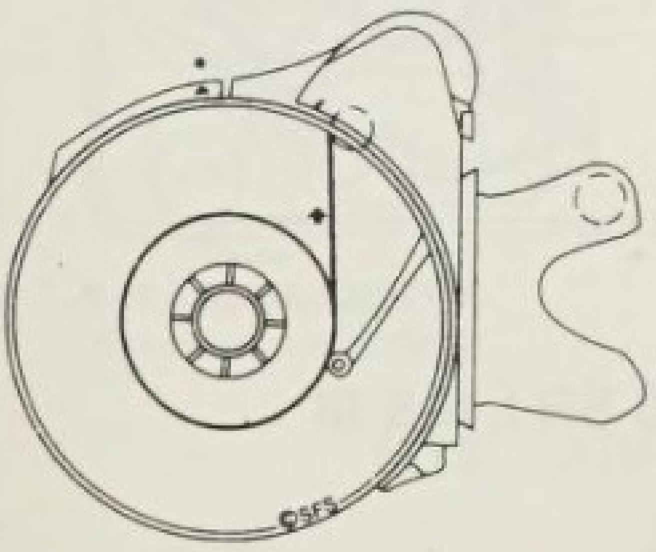
Supply side



Take-up side
Film takes up emulsion in

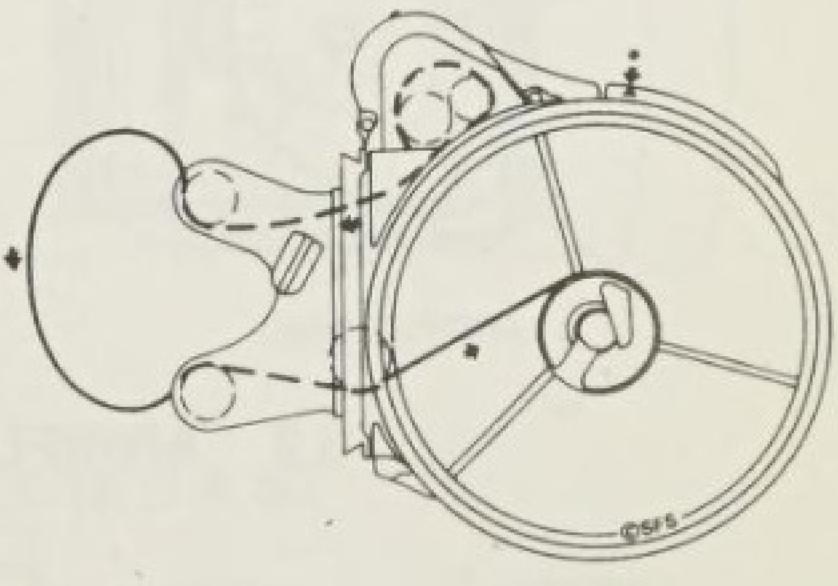


6.7 ARRIFLEX 35BL I, II, III, IV & IVs

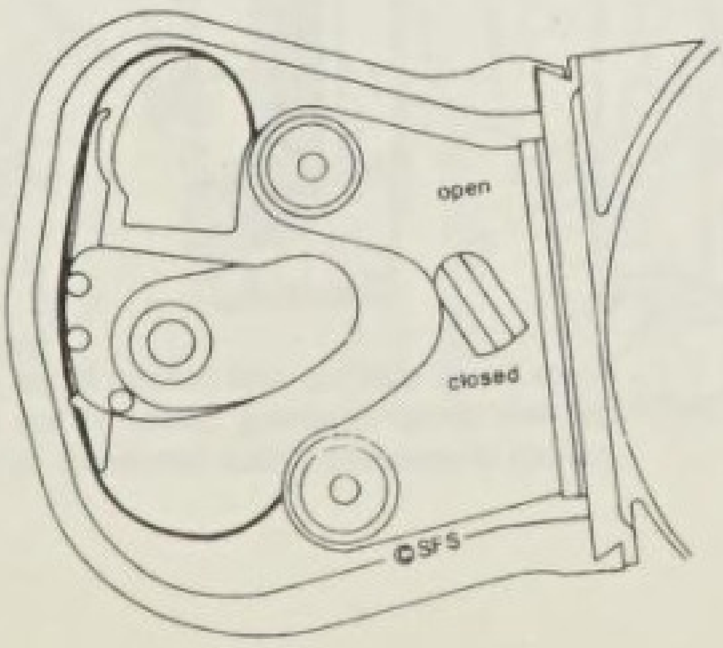


Supply side

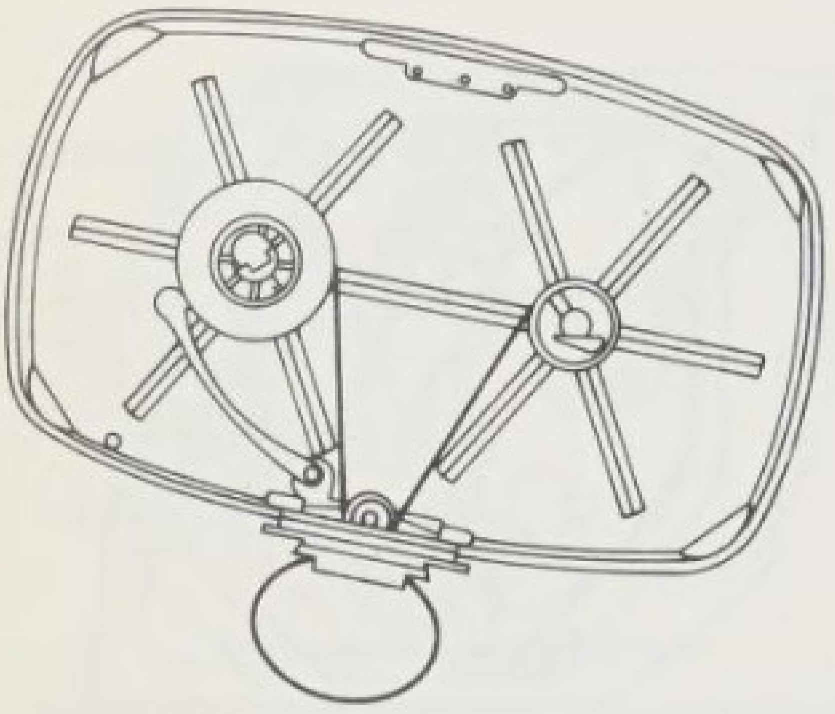
* Loop measurement mark



Take-up side
Film takes up emulsion in

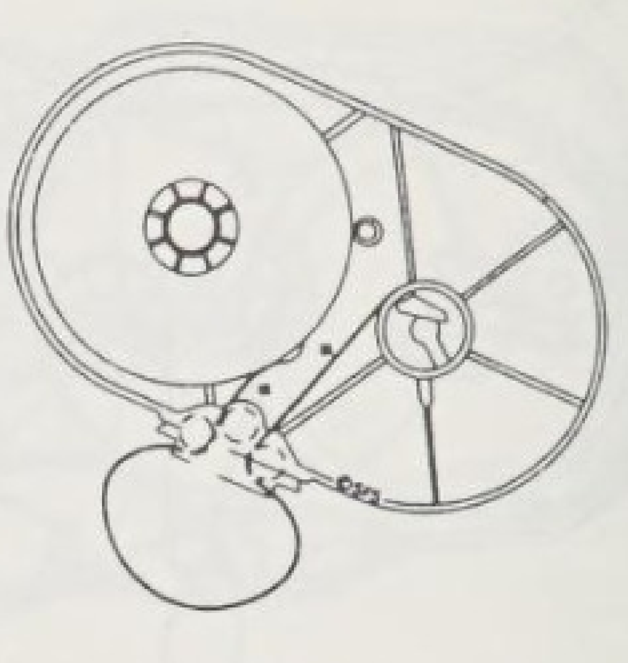


6.8 ARRIFLEX 35 IIB & IIC, 35 IIIC & 35-3

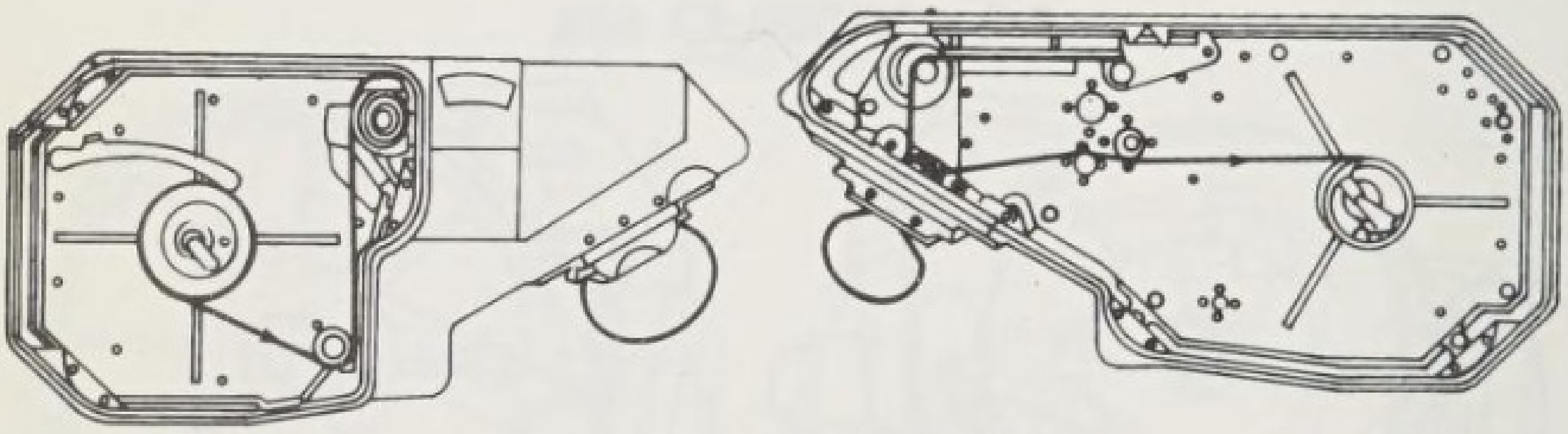


1000' magazine
Film takes up emulsion in

* Loop measurement mark



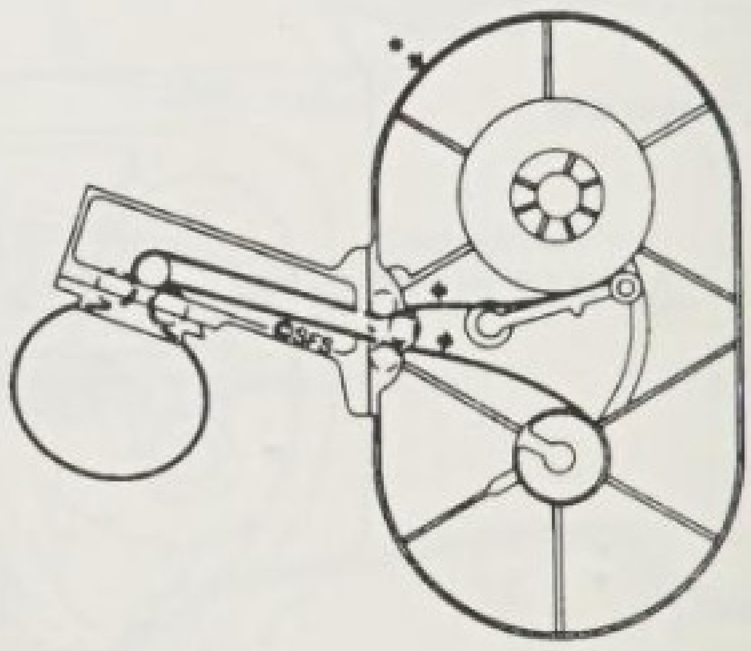
Normal (200' & 400') magazines
Film takes up emulsion in



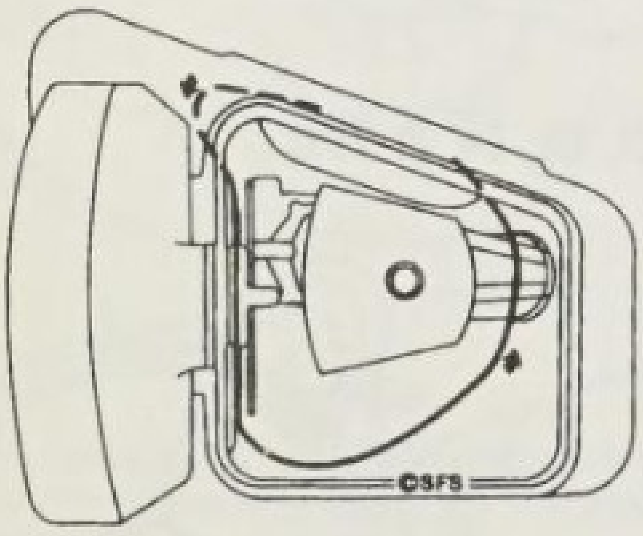
Supply side

Coaxial type shoulder magazine
* Loop measurement mark

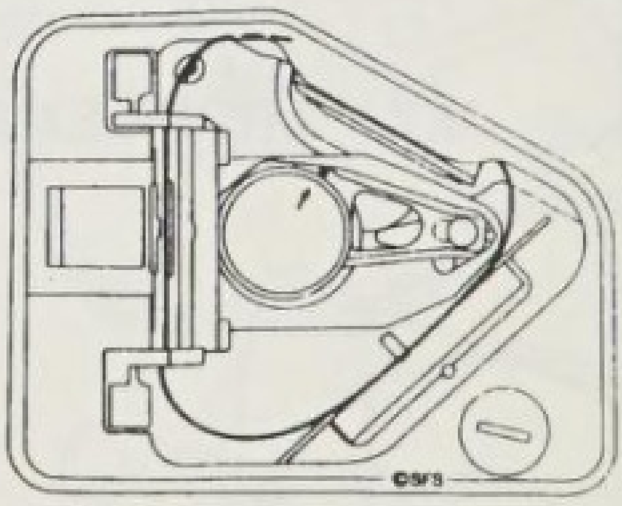
Take-up side
Film takes up emulsion in



Throated type shoulder magazine
* Loop measurement mark
Film takes up emulsion in

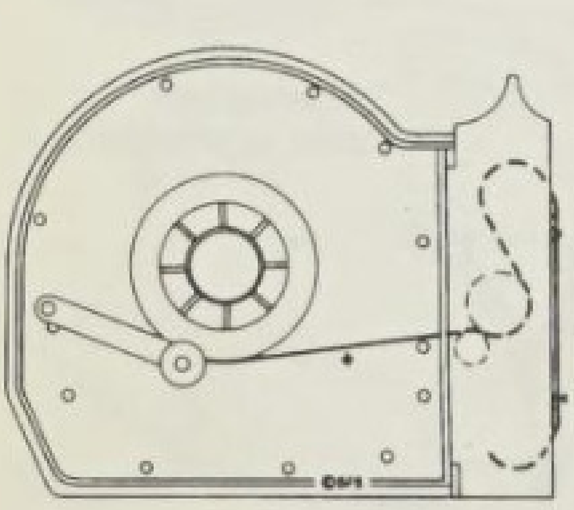


ARRIFLEX 35IIC

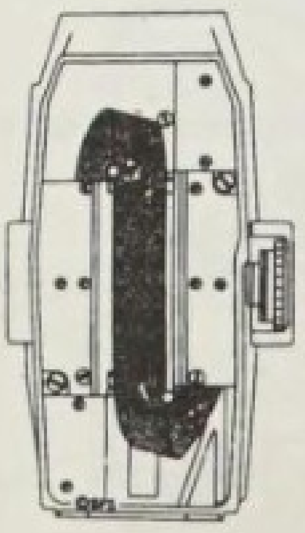


ARRIFLEX 35 IIIC & 35-3

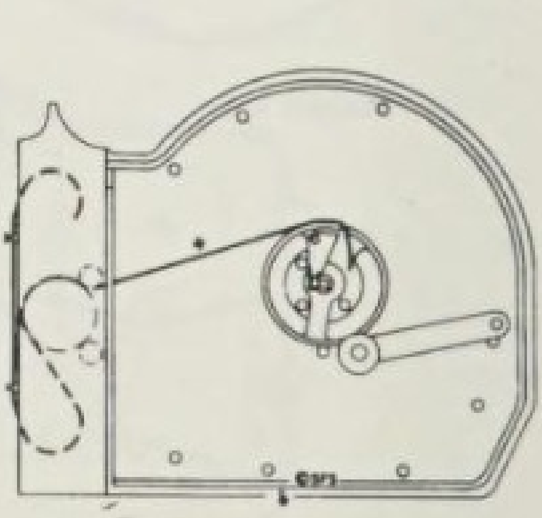
6.9 ARRIFLEX 16 SR I, II & III



Supply side

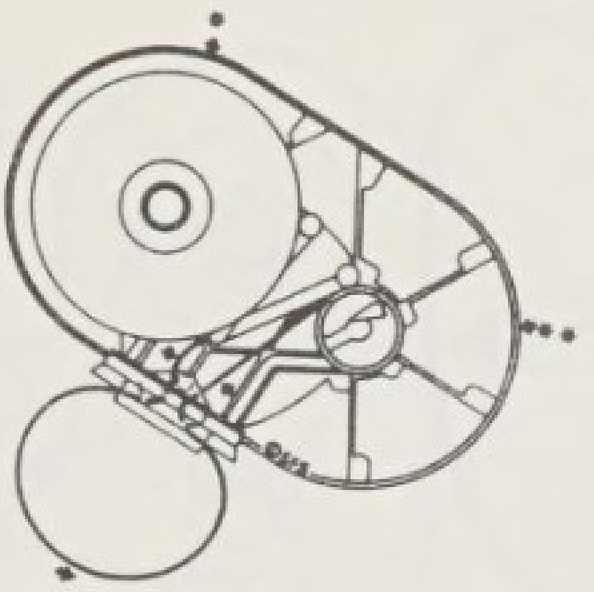


Form equal size top and bottom loops and set film under retaining hooks at top and bottom of pressure plates (arrowed)

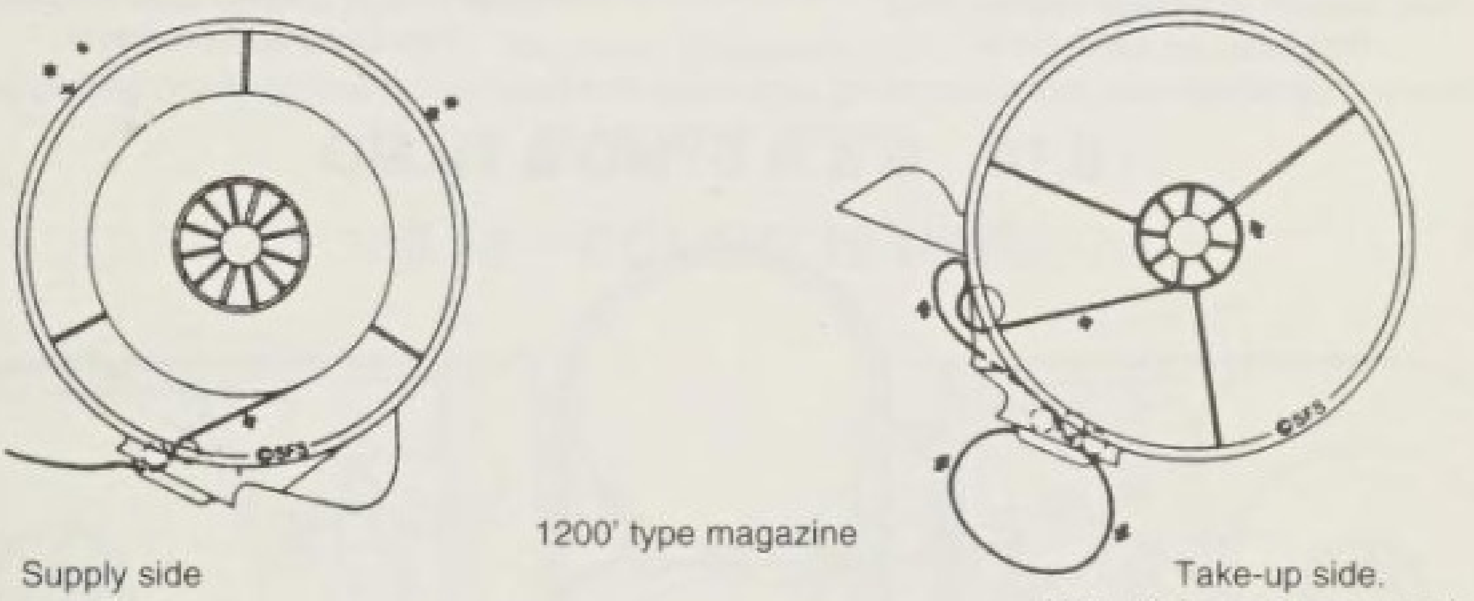


Take-up side
* Loop measurement mark
Film takes up emulsion in

6.10 ARRIFLEX 16 BL



400' type magazine
Film takes up emulsion in

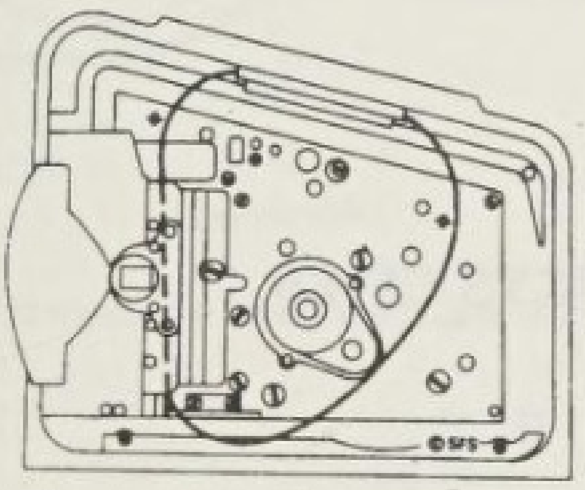


1200' type magazine

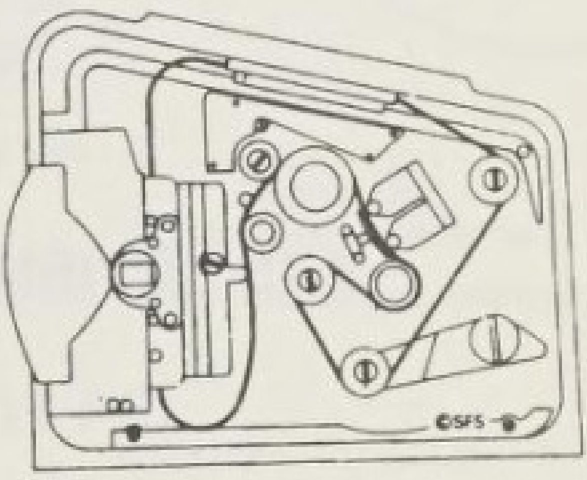
Supply side

Take-up side.
Note 19 frame cross-over loop
Film takes up emulsion in

* Loop marker for double system sound ** Loop marker for single system sound

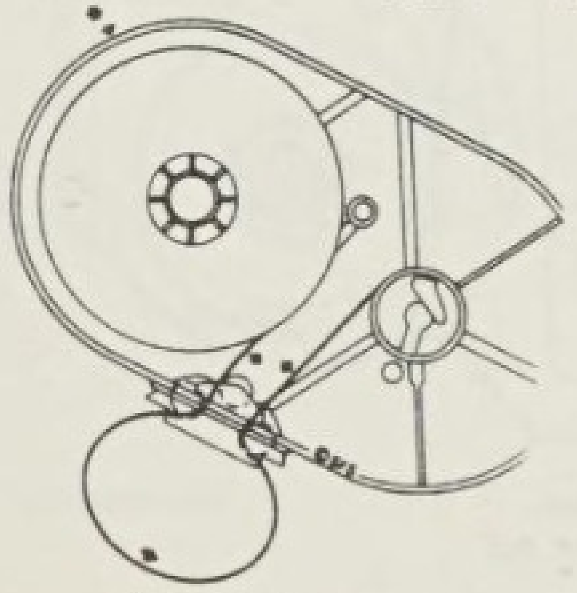


Double system sound camera threading

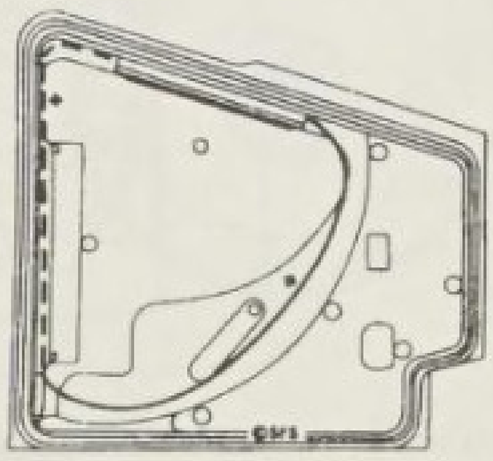


Single system sound camera threading

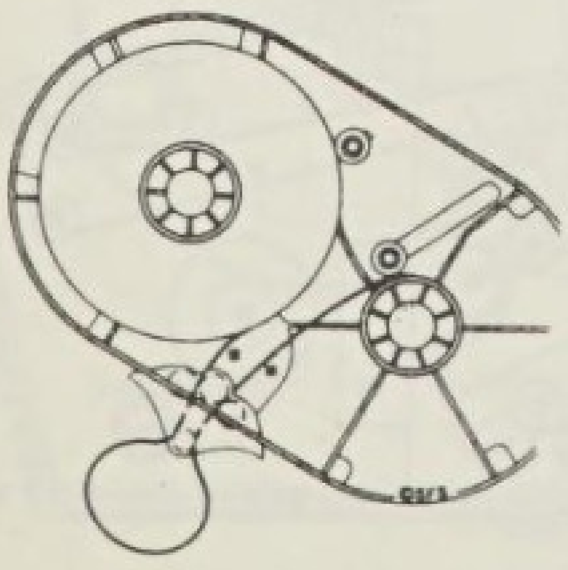
6.11 ARRIFLEX 16 M



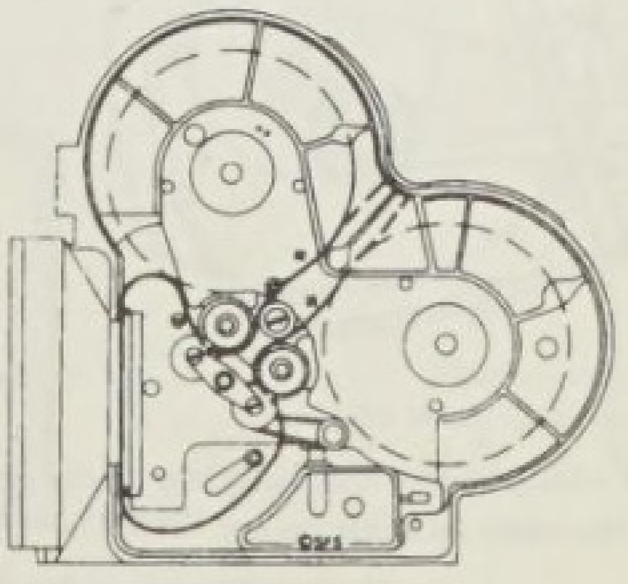
* Loop marker
Film takes up emulsion in



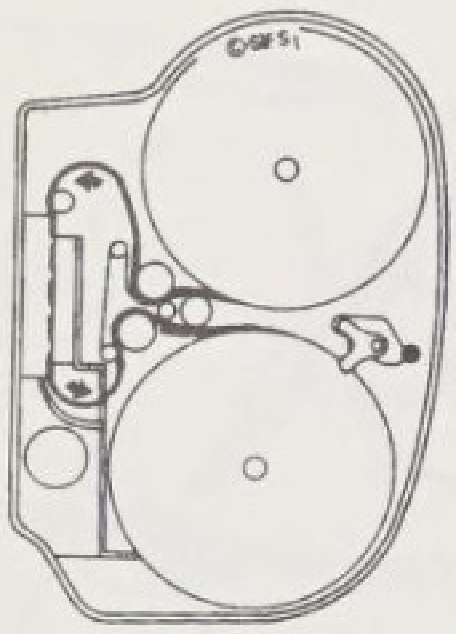
6.12 ARRIFLEX 16 S & ST



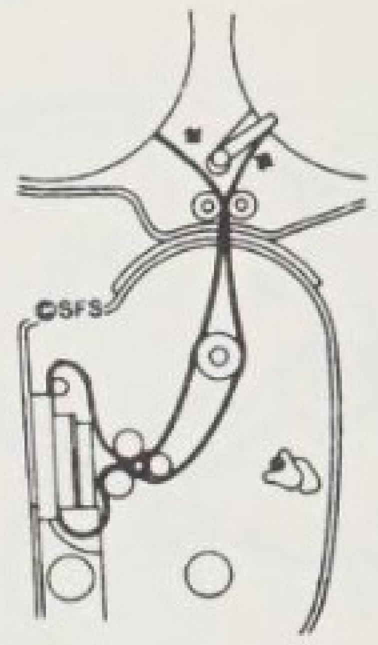
Film takes up emulsion in



6.13 BEAULIEU 16

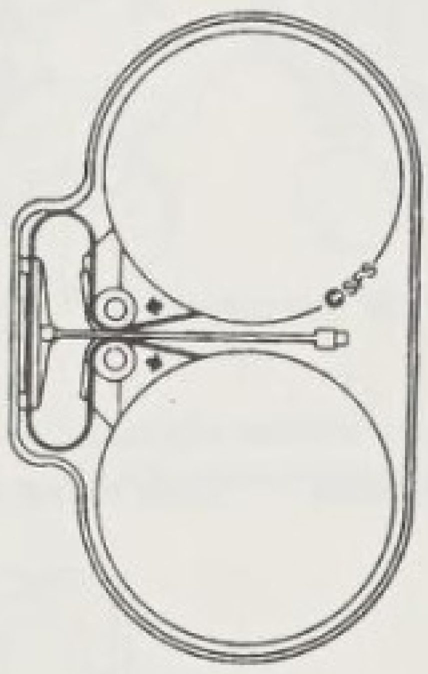


Threading for 100' daylight spools
(Note position of footage counter lever)
Film takes up emulsion in



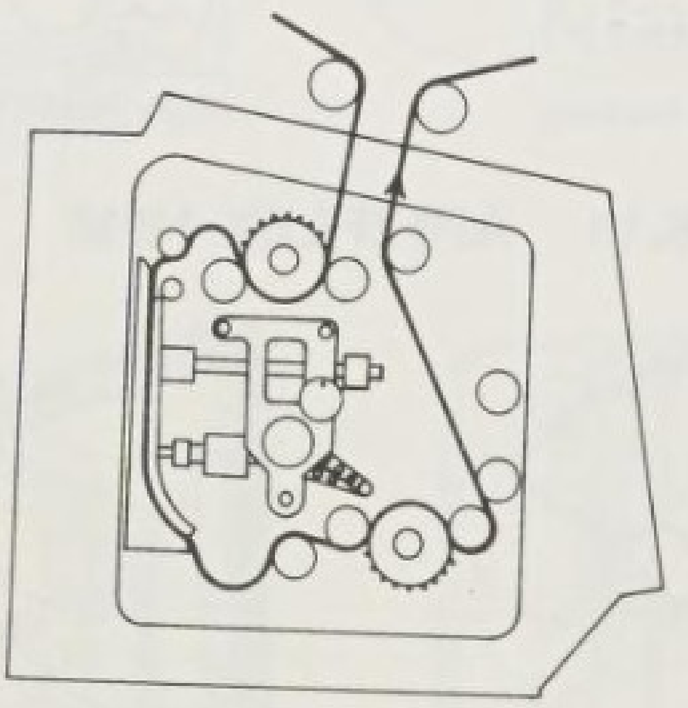
Threading for 200' magazine
(Note footage counter lever inhibited)
Film takes up emulsion in

6.14 B & H EYMO & FILMO



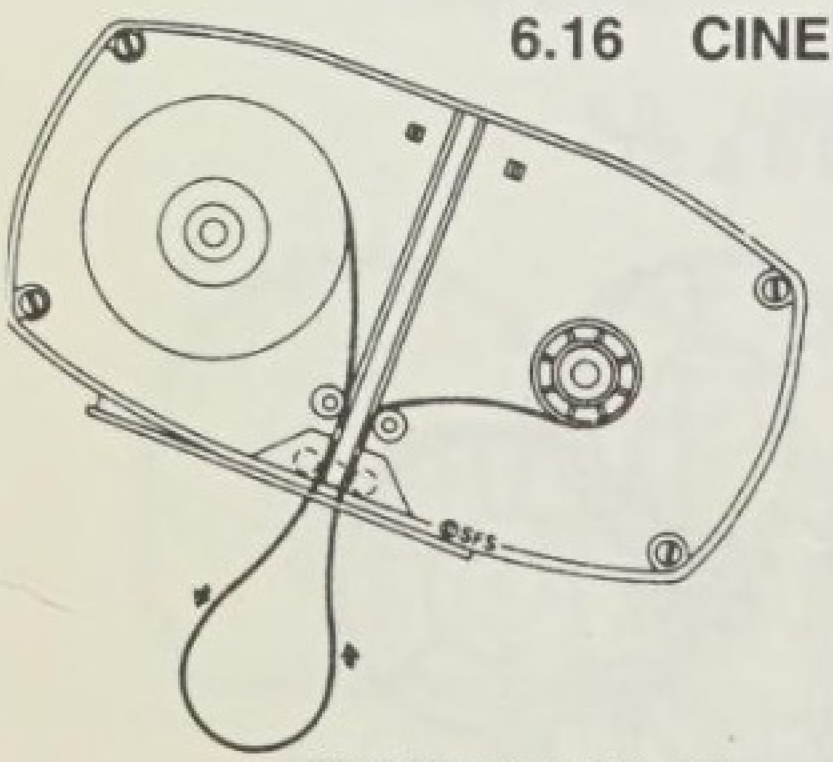
Film takes up emulsion in

6.15 CINEMA PRODUCTS CP-65

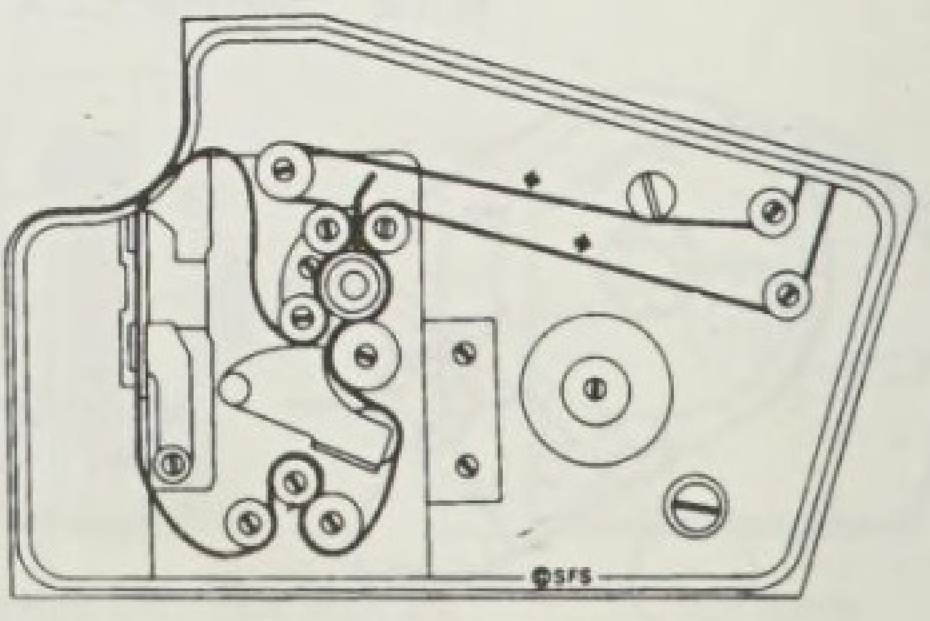


Magazine as Mitchell
Film takes up emulsion out

6.16 CINEMA PRODUCTS CP-16

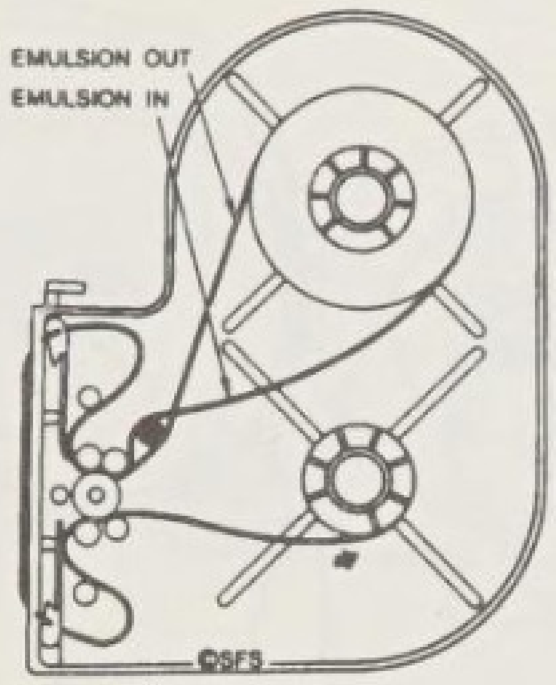


Film takes up emulsion out



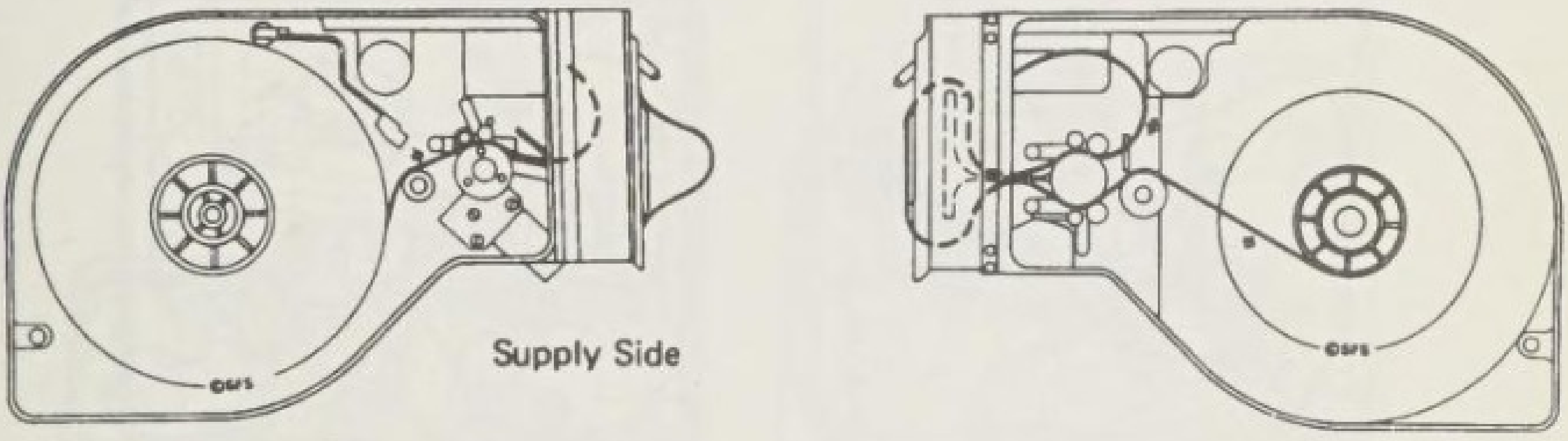
(Auricon Cinevoice, Pro 600 and Pro 1200 are similar)

6.17 ECLAIR CM3 (CAMEFLEX)



Film takes up emulsion out
Form loop by placing one finger inside loop level with top of front of magazine and pushing film back into magazine equally top and bottom

6.18 ECLAIR 16 NPR

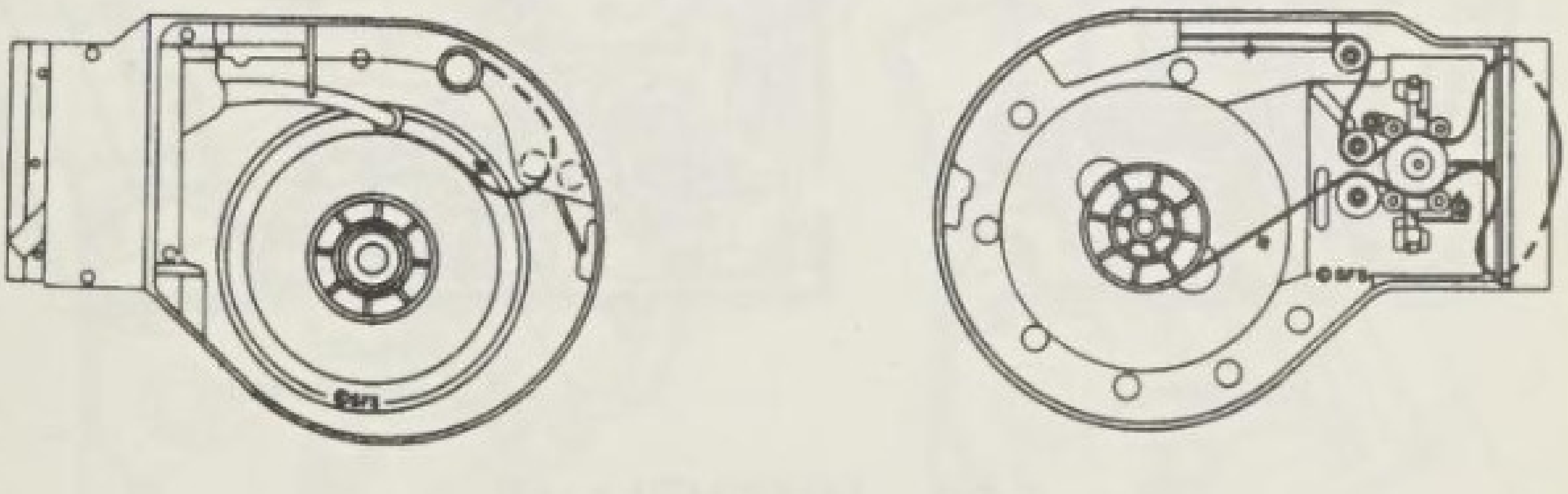


Supply side

Take-up side
Film takes up emulsion out

Form 12 frame loop (about two fingers width) and push equally into magazine to form top and bottom loops

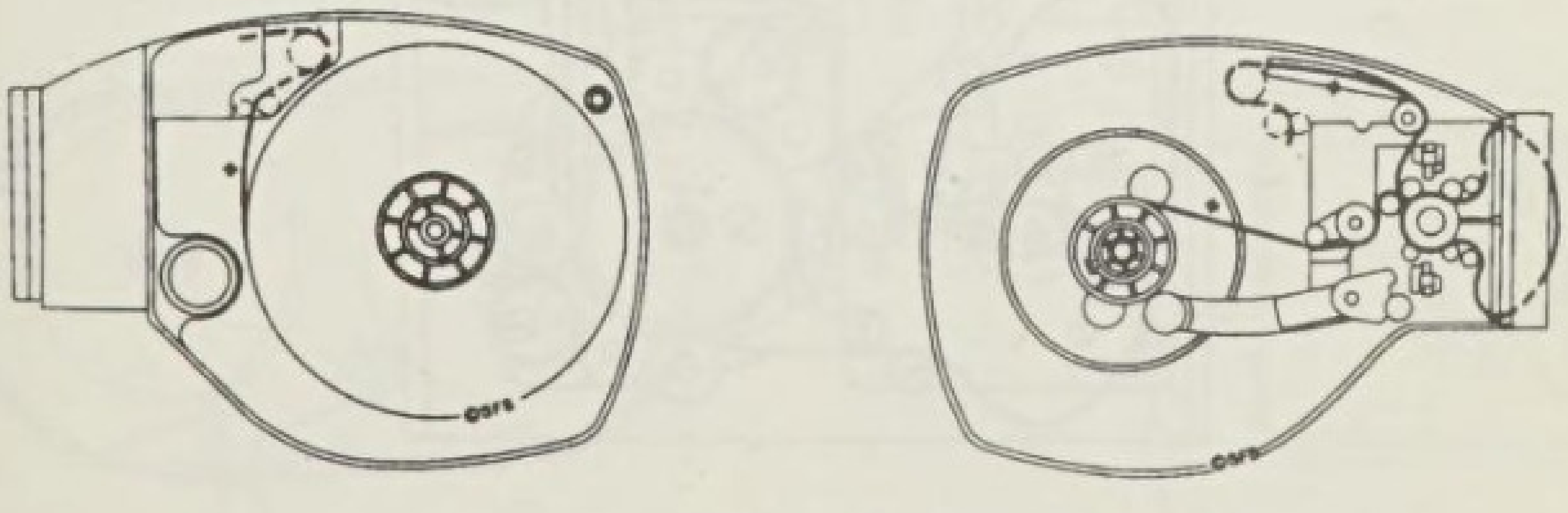
6.19 ECLAIR 16 ACL



Supply side

200' magazine

Take-up side
Film takes up emulsion out



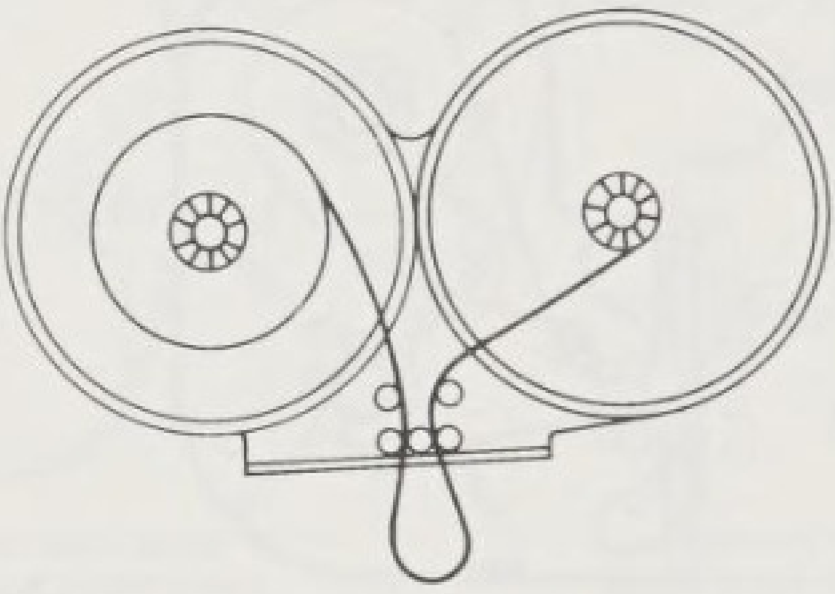
Supply side

400' magazine

Take-up side
Film takes up emulsion in

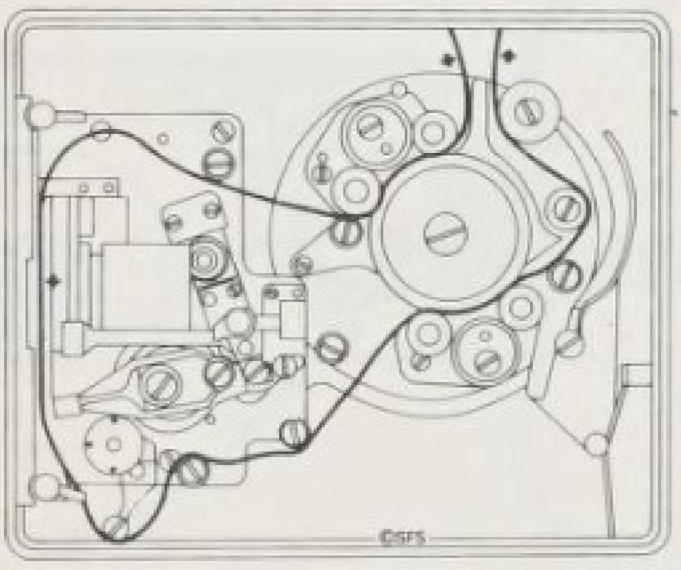
Form loop by making film level with top of camera (no fingers inside) and push back into magazine making bottom loop one frame larger than top

6.20 MITCHELL BNC, NC, etc. MITCHELL STANDARD & HIGH-SPEED

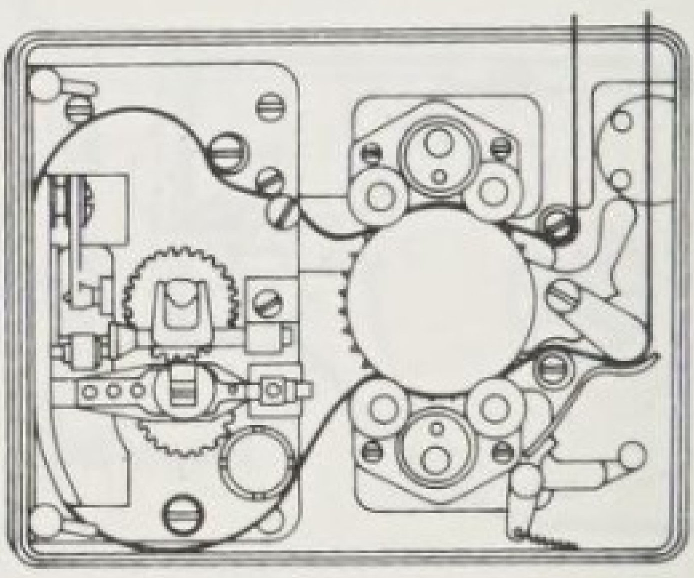


Mitchell magazine

Film takes up emulsion out
Panavision 65mm and PSR are similar

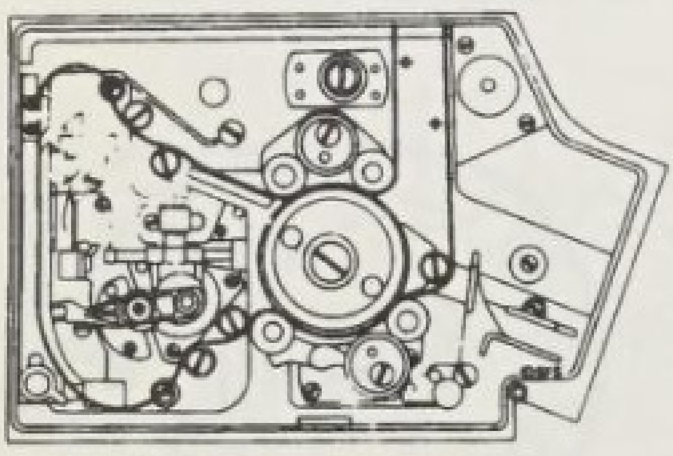


Mitchell NC & BNC

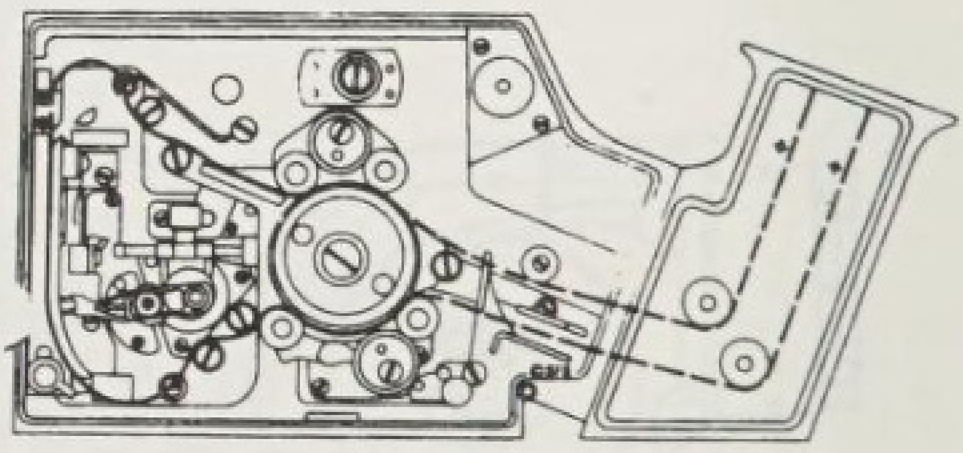


Mitchell Standard and High Speed

6.21 MITCHELL S35 MkII

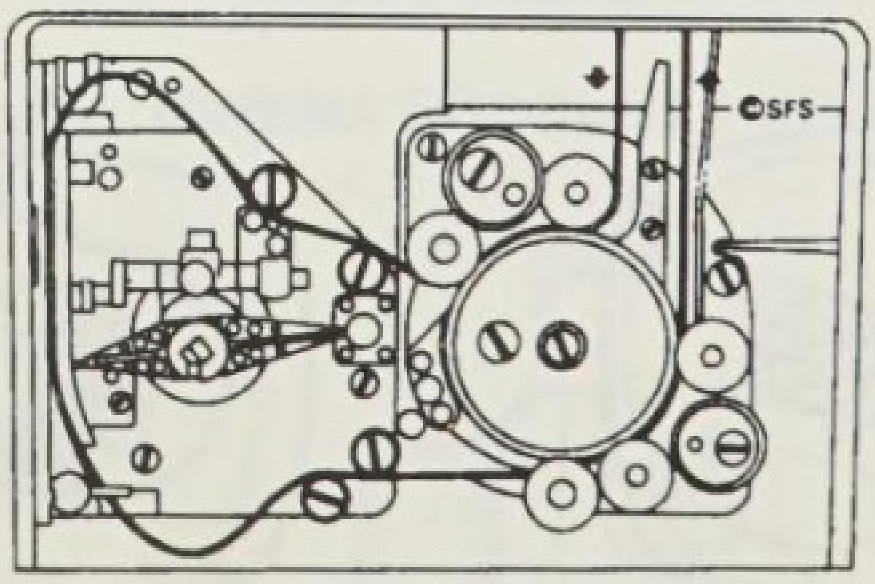


Top loading

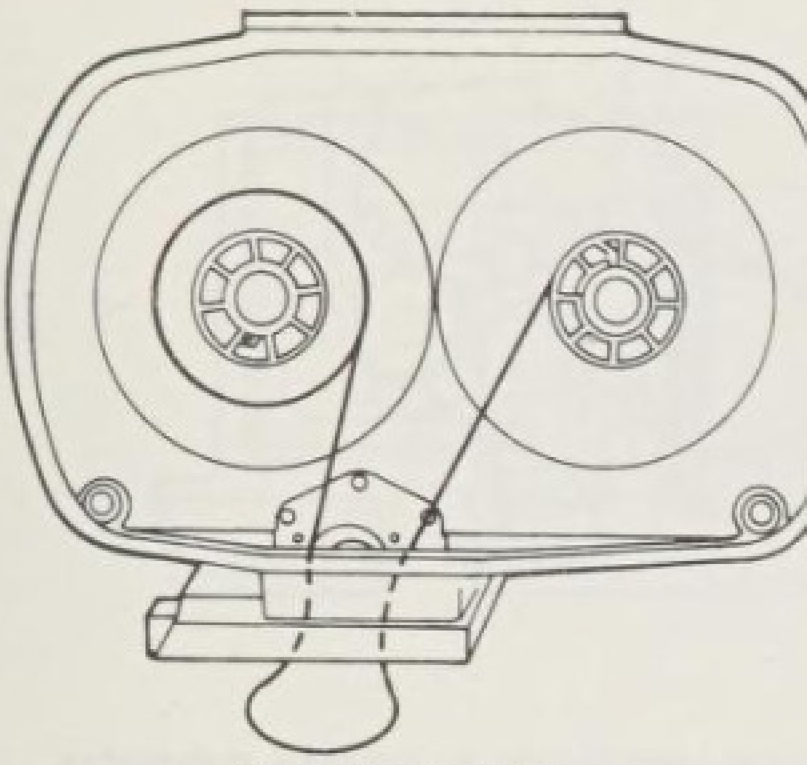


Slant loading

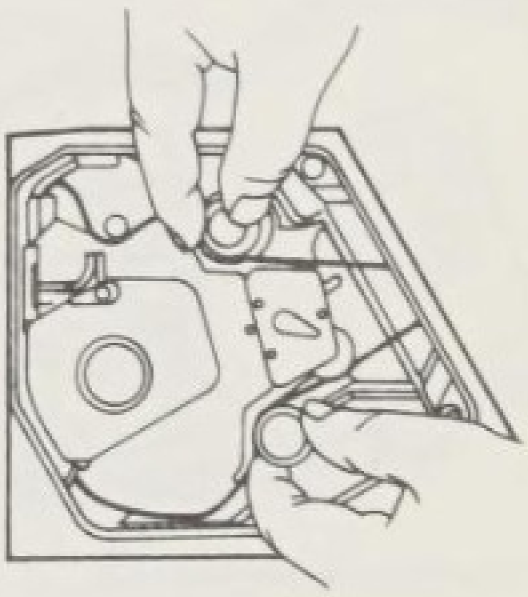
6.22 MITCHELL 16



6.23 MOVIECAM

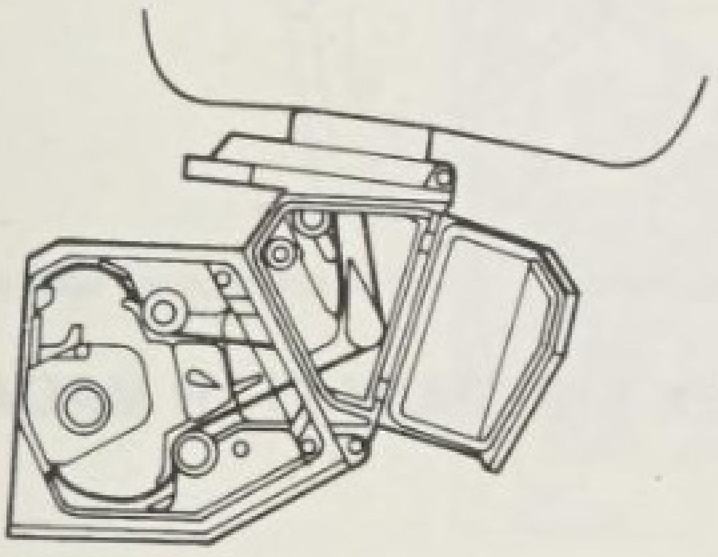


Moviecam magazine
Film takes up emulsion in

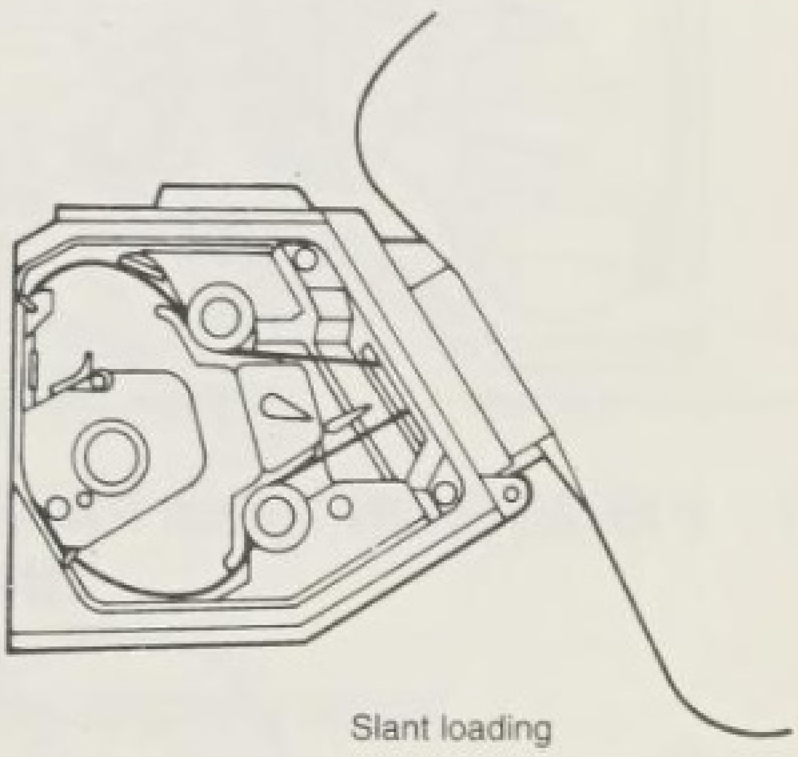


Loop adjustment

6.23.1 Moviecam Superamerica

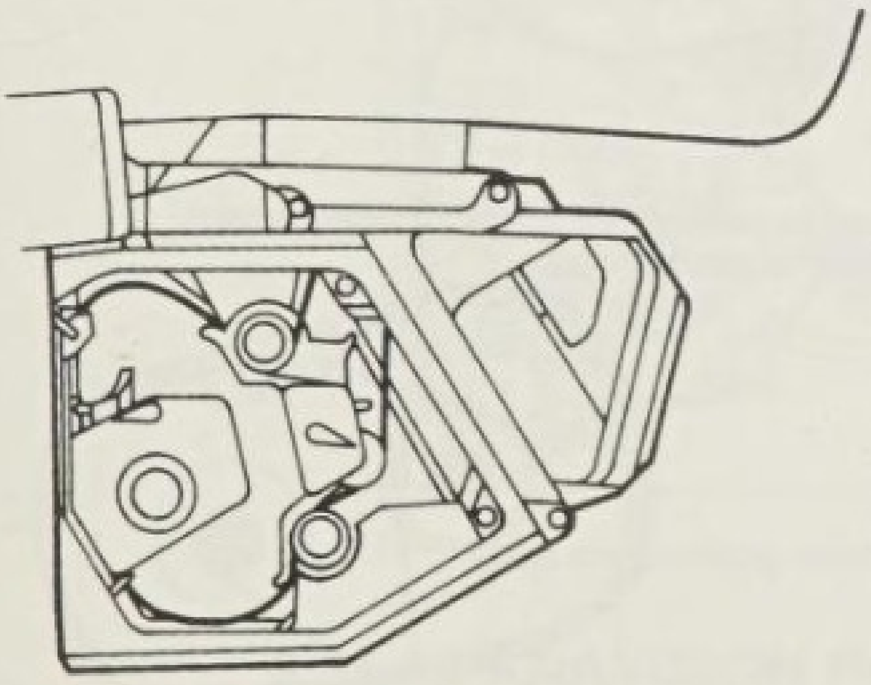


Top loading

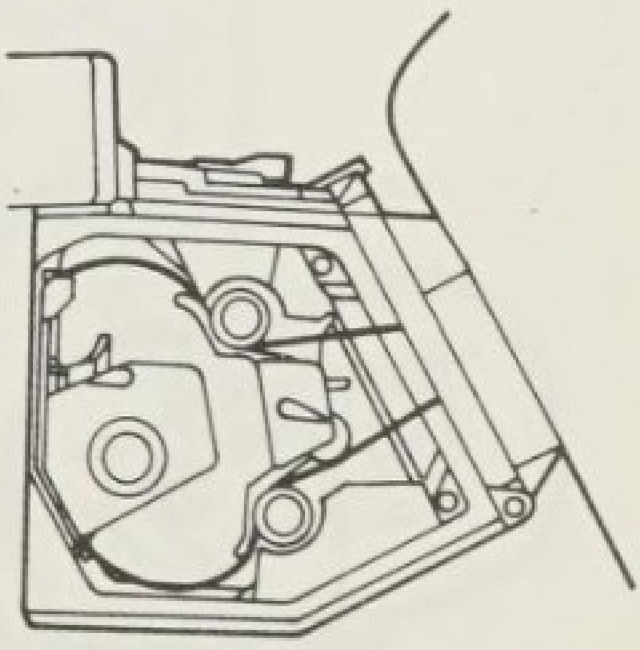


Slant loading

6.23.2 Moviecam Compact

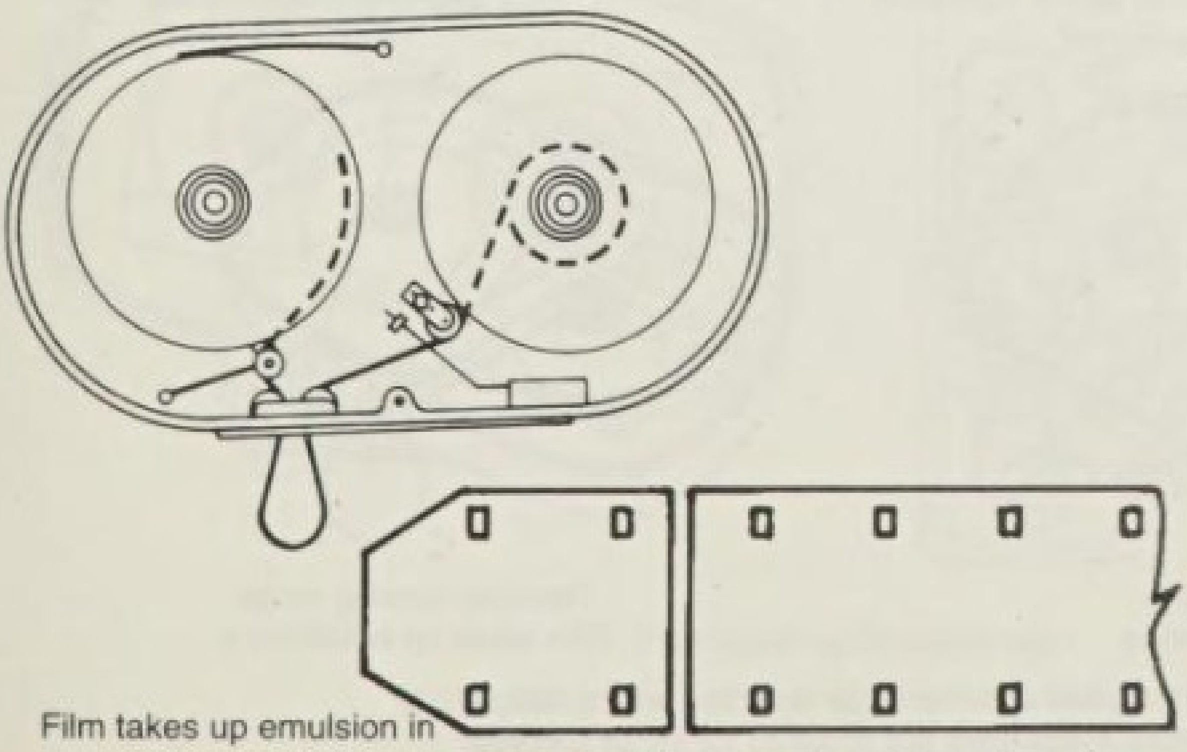


Top loading



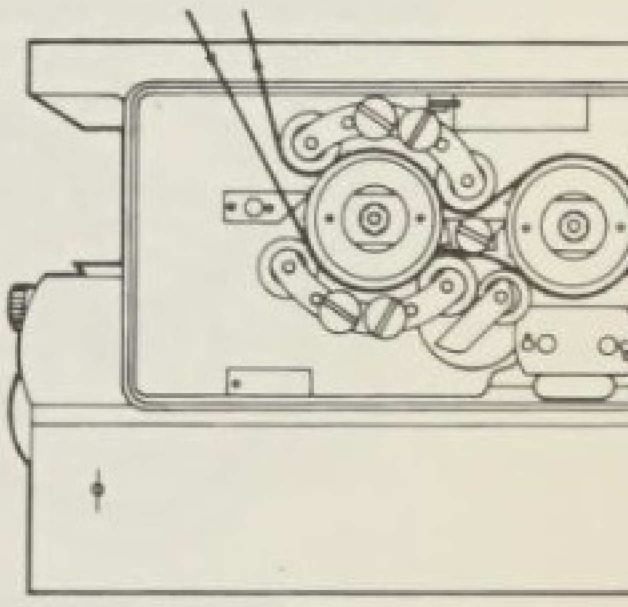
Slant loading

6.24 NAC E-10

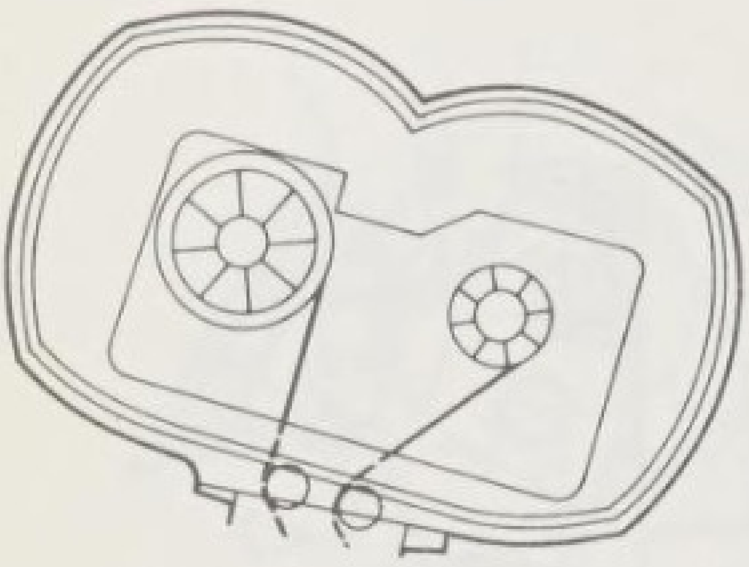


Film takes up emulsion in

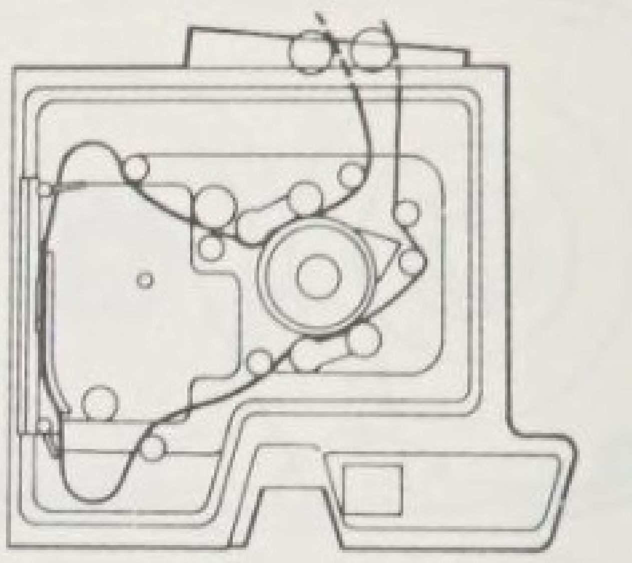
Cut film squarely to flatten film edge



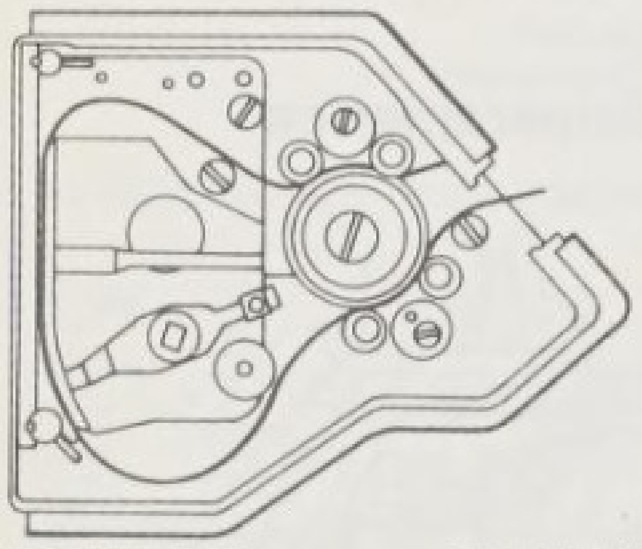
6.25 PANAVISION PANAFLEX 65

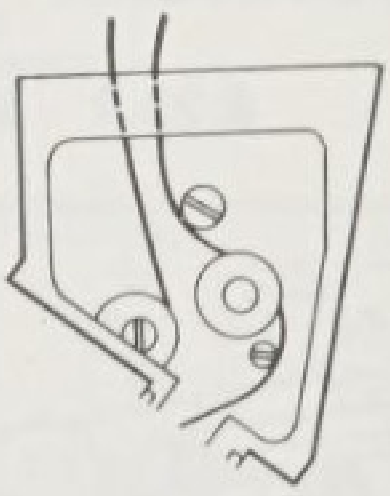


Film takes up emulsion out



6.26 PANAVISION 65mm LIGHTWEIGHT & HIGH-SPEED



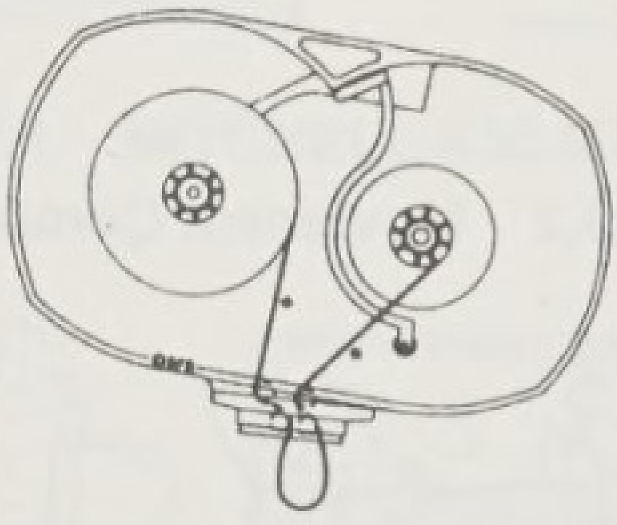


Hand-holdable mode

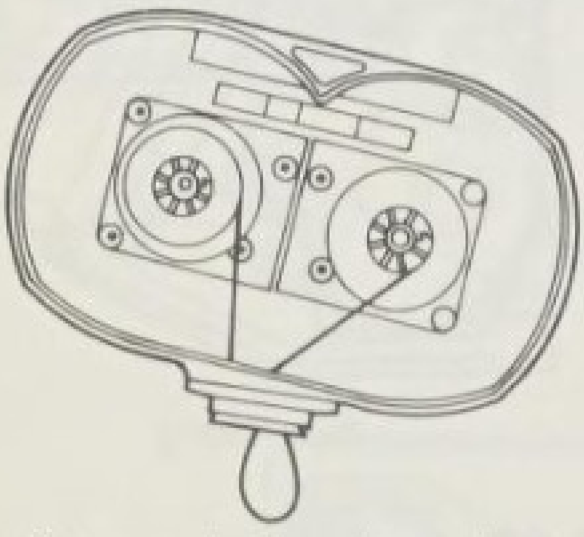
Magazine threading as Mitchell NC

Top-mount magazine adaptor

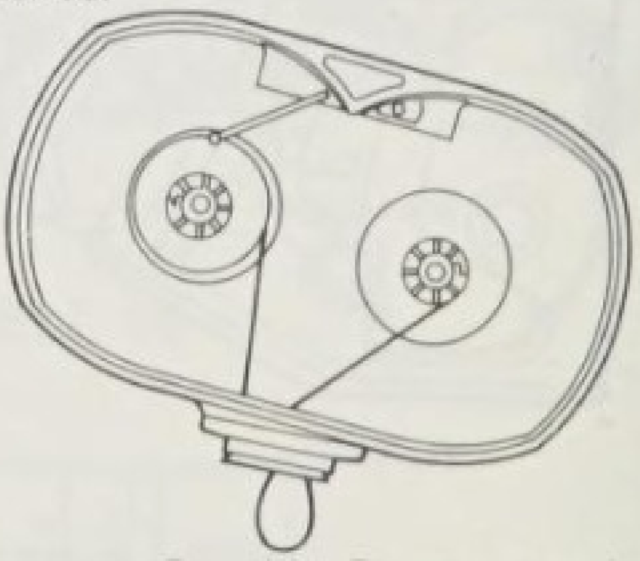
6.27 PANAVISION 35mm PANAFLEX AND PANASTAR MAGAZINES



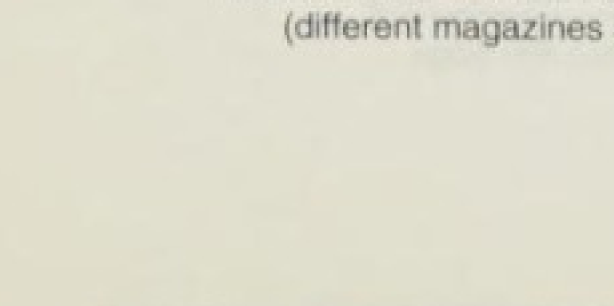
Normal Panaflex magazine (may be used on any 35mm Panaflex camera)
Film takes up emulsion out



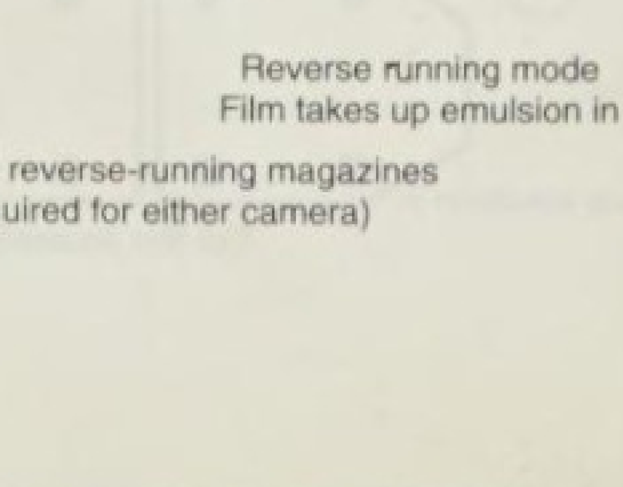
Platinum Panaflex magazine (may be used on any 35mm Panaflex but with reduced facilities on earlier cameras)
Film takes up emulsion out



Panavision Panastar magazine
Film takes up emulsion out



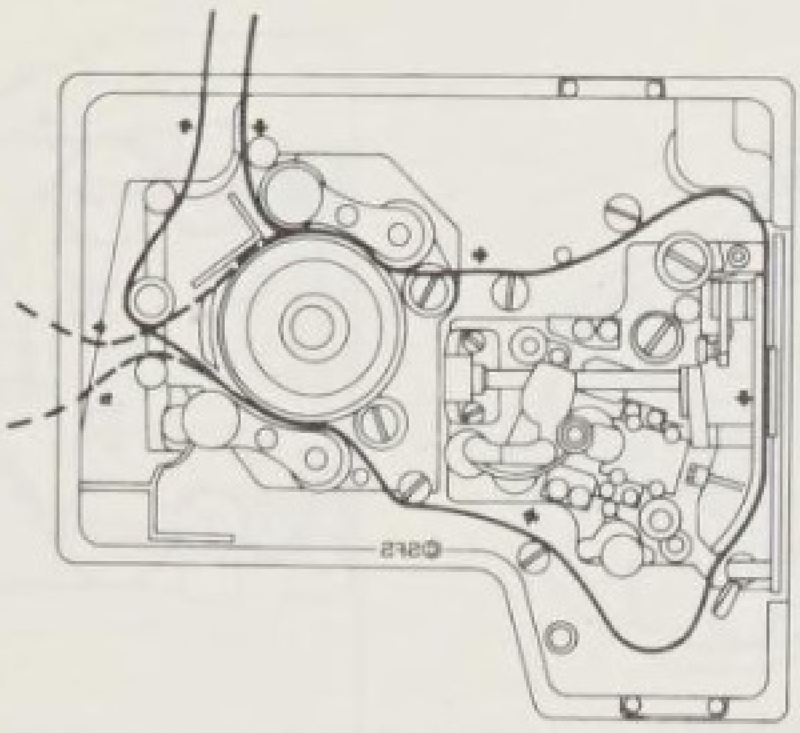
Forward running mode
Film takes up emulsion in



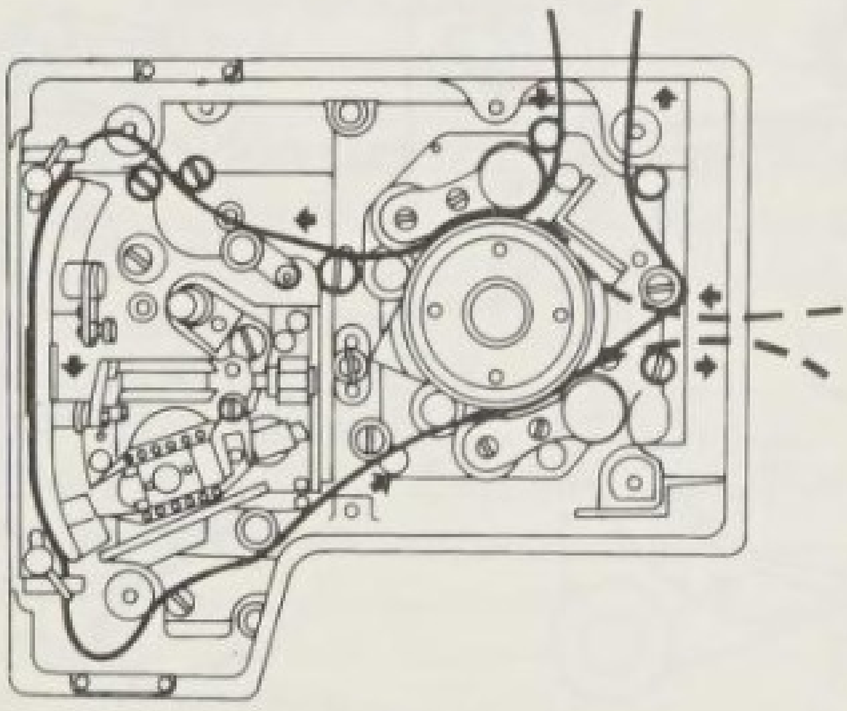
Reverse running mode
Film takes up emulsion in

Platinum Panaflex and Panastar reverse-running magazines
(different magazines are required for either camera)

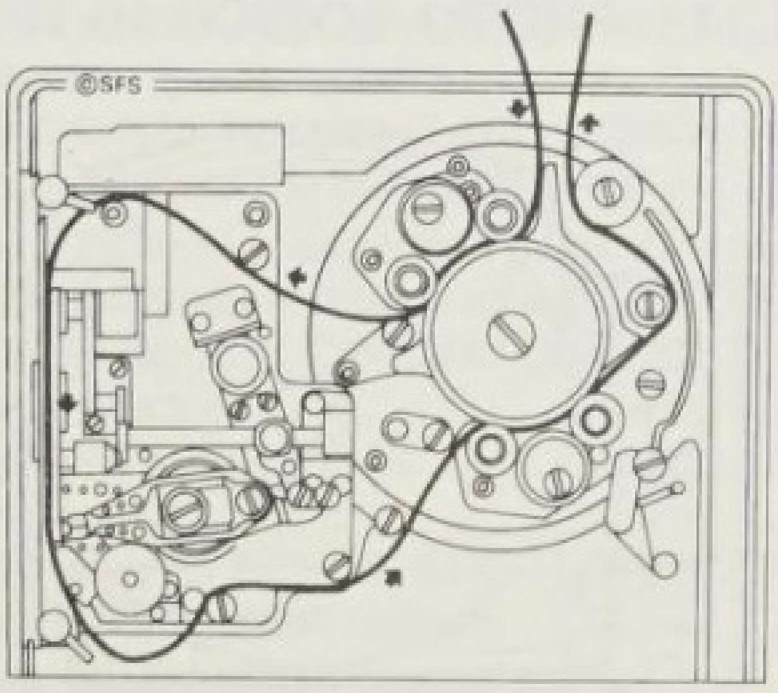
6.28 PANAVISION 35mm PANAFLEX



6.29 PANAVISION PANASTAR

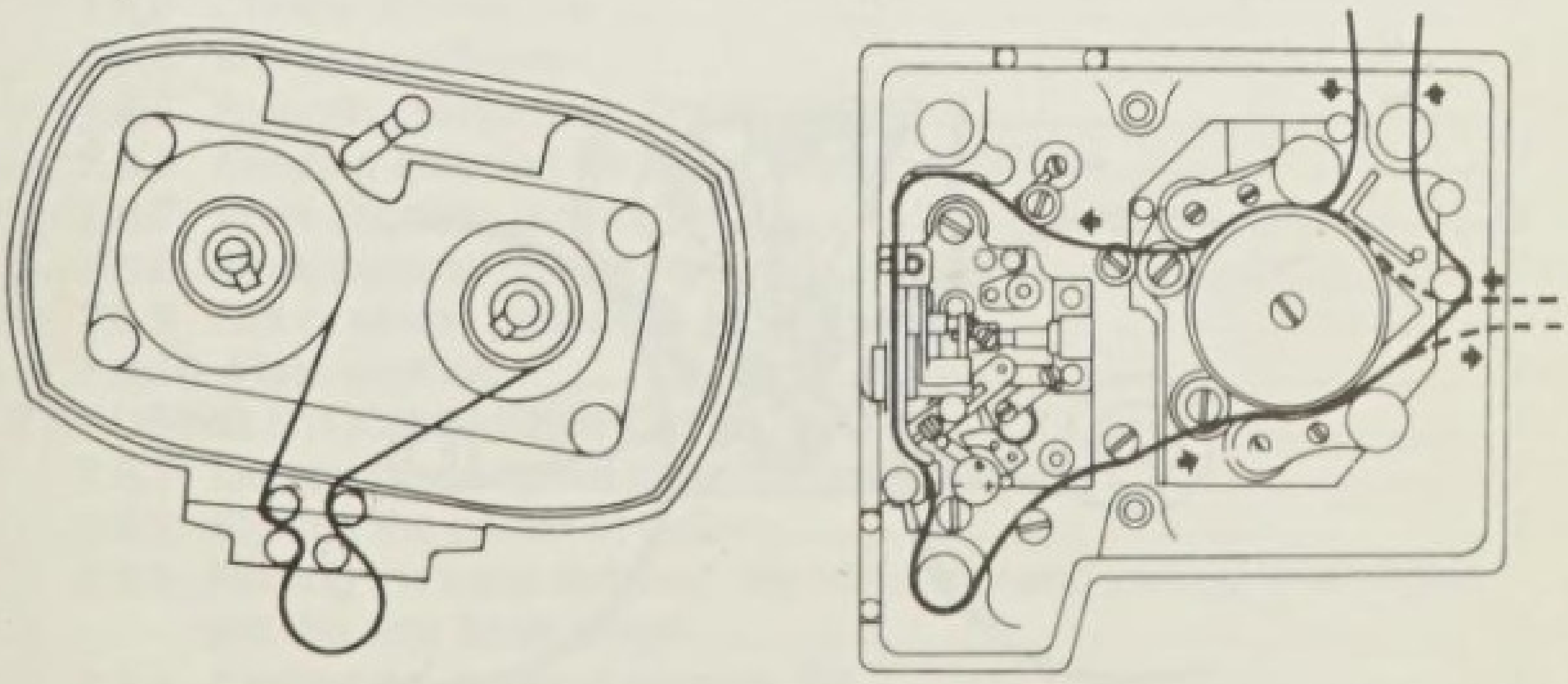


6.30 PANAVISION SUPER R200°



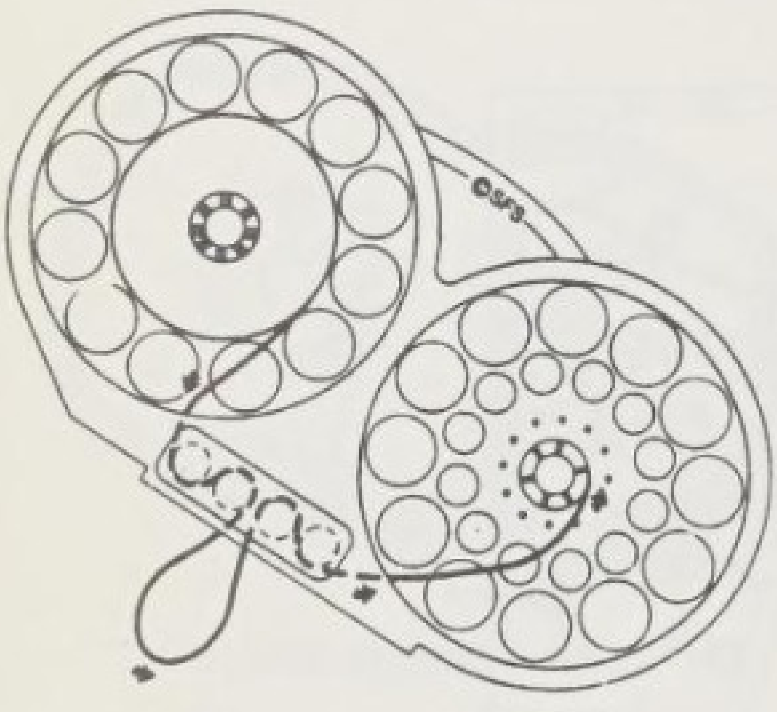
Magazine threading as Mitchell NC

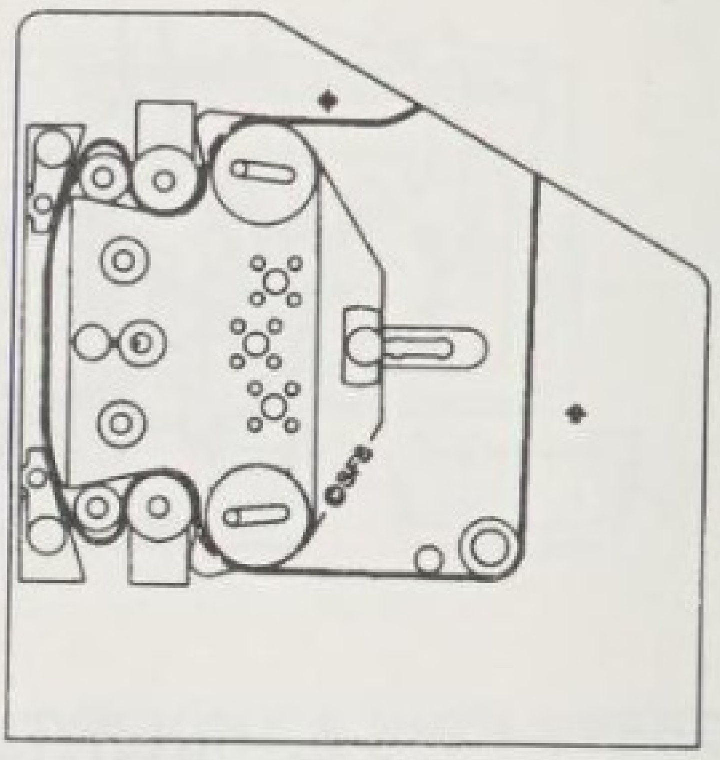
6.31 PANAVISION PANAFLEX 16



Film takes up emulsion out

6.32 PHOTO-SONICS 35 4E & 4ER





Film takes up emulsion out

6.33 PHOTO-SONICS 35 4B

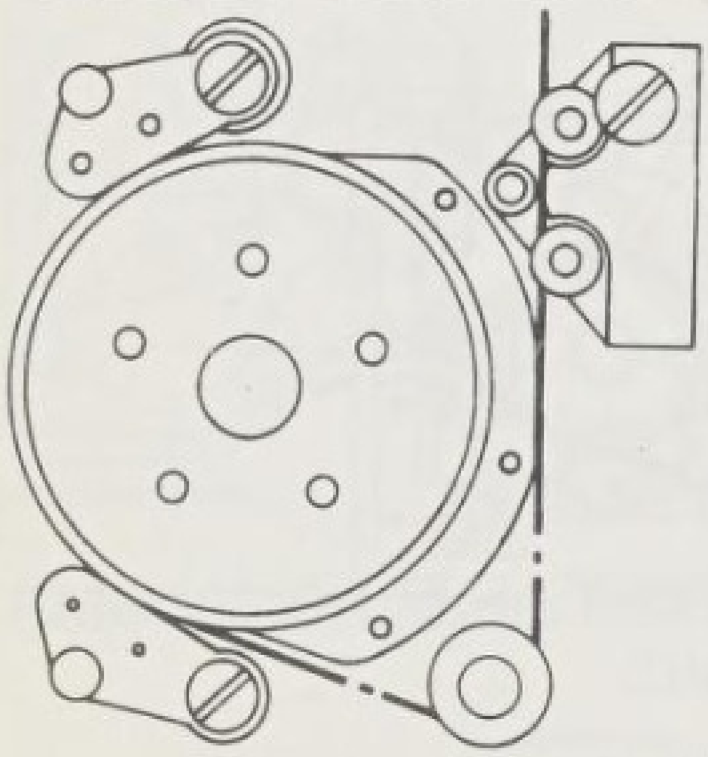
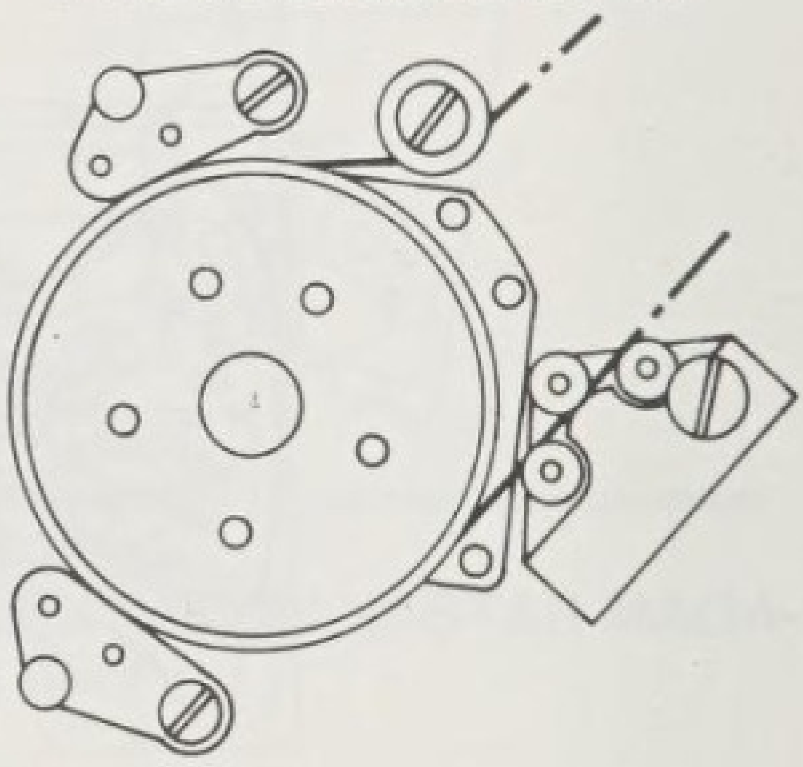
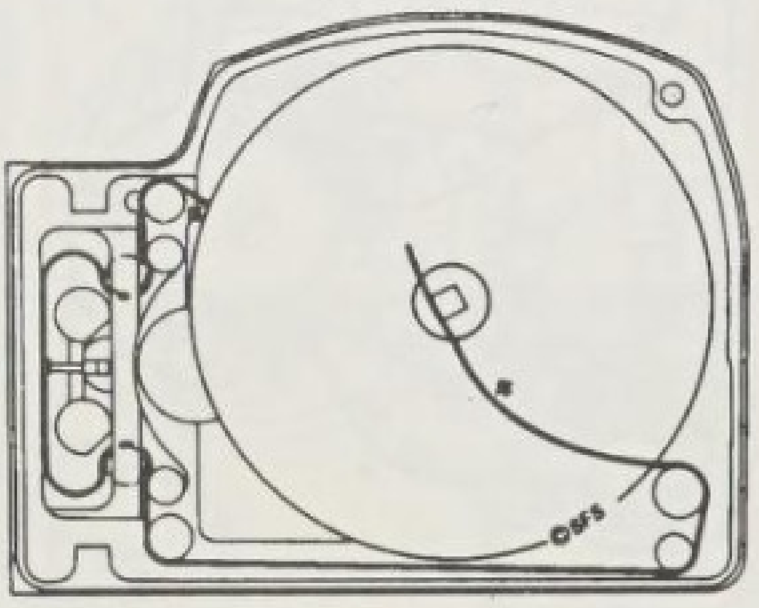


PHOTO-SONICS 35 4C



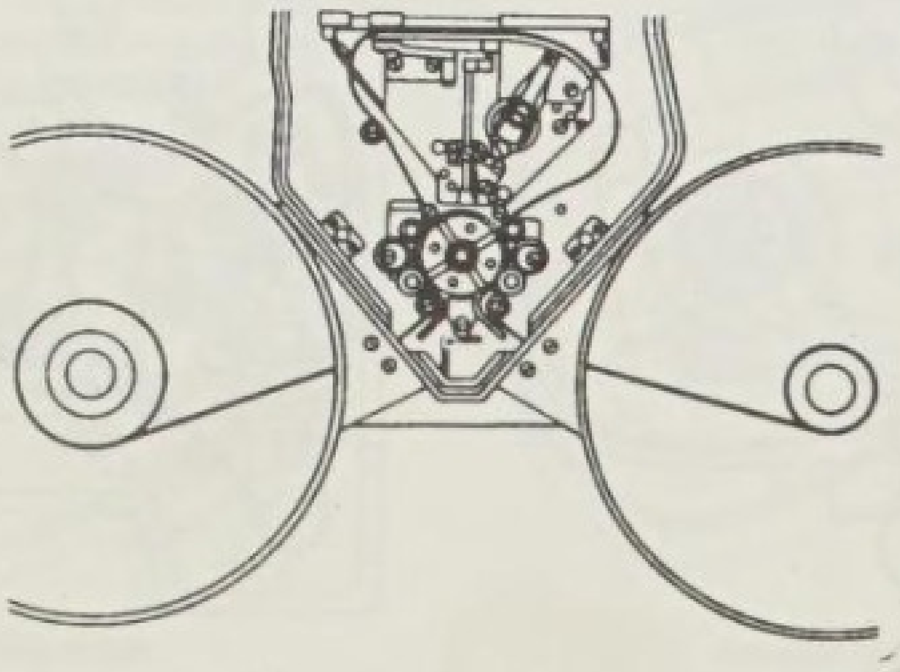
Magazine threading similar to Photosonics 35 4E

6.34 PHOTO-SONICS 16 1PD



Film takes up emulsion in
(Take-up spool not shown)

6.35 VISTAVISION, BUTTERFLY TYPE



Film takes up emulsion in

7 COMPOSITE CINEMATOGRAPHY

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The art and practice of combining multiple images to create a single, seamless, image that looks as though it was all photographed at the same time and blends in with the rest of the production is almost as old as cinematography itself.

Whereas at the turn of the twentieth century it consisted of no more than rewinding the film in the camera and exposing it a second time, nowadays there are a wide variety of methods, many of them involving computers and electronics and other specialist techniques, very often complicated and demanding of the most painstaking care, usually frustrating and time consuming, and almost always expensive.

Having said that, there are many scripts that are only written in the knowledge that what they call for in terms of visual effects will be possible and that the general audience will accept what they see as being feasible.

While some aspects of composite cinematography are so highly specialized that only the very few who actually have to carry out the tasks involved have gained the necessary skills, there are other aspects that involve many others on the studio floor and for them an overall working knowledge is sufficient. The expertise comes with practice and with experience and by working with others who are already highly skilled.

7.1 ON-FLOOR METHODS

1. Blue screen travelling matte

Artists or objects in the foreground are photographed against an intensely blue background. The background image is used subsequently as a matte in the optical printing process.

2. Computer manipulated images

Images are created on film in the normal manner and transferred to computer by digitization. The images can then be modified, manipulated and massaged, pixel by pixel, before being transferred back to film with little or no loss of image quality.

3 & 4. Front and rear projection

A still or motion picture image is projected simultaneously with the foreground action. The background is rephotographed at the same time as the original photography of the foreground action takes place.

5. Glass shots and photo cut-outs

A scale image is accurately painted on a sheet of glass and is used to add to, or to replace a part of, an existing image. A cut-out still photograph can be used in place of the glass painting. The glass or the photo cut-out is firmly fixed at an appropriate distance in front of the live action where the depth of field of the foreground matches that of the background.

6. Hanging miniatures and scale models

Typically, a scale model of the upper part of a building or room may be hung in front of the camera and photographed while action takes place below. This saves building a very expensive upper part of a set which may only be used for one brief establishing shot.

7. Motion control

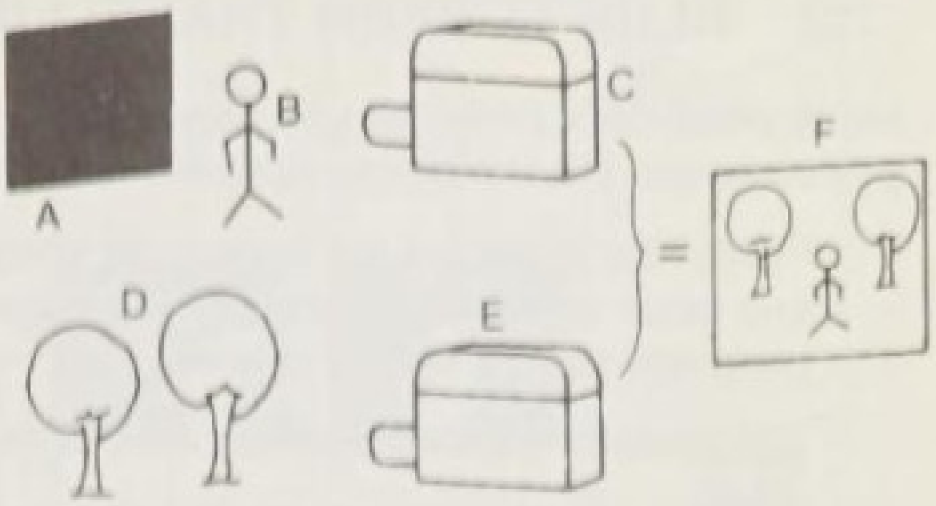
All the original camera movements are either created or recorded on a computer which is then used to control the camera movements on subsequent passes enabling a multitude of photographic elements to be created each with identical camera moves. The elements are then combined together, either in the camera or on an optical printer.

Optical printing

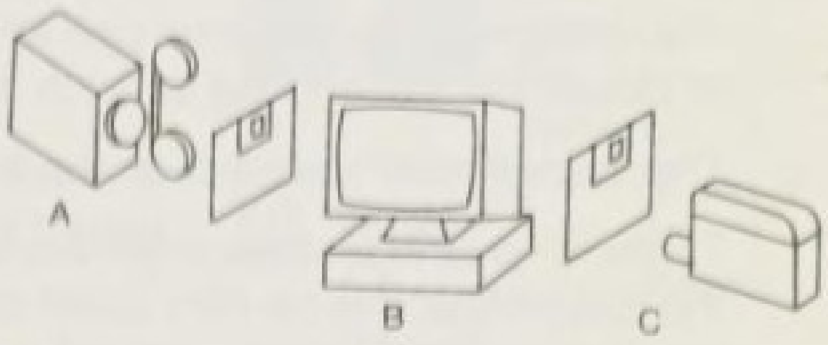
The key to almost all forms of process photography is the bringing together of all the elements on an optical printer to produce an internegative that can be edited into the whole picture.

PROCESS PHOTOGRAPHY

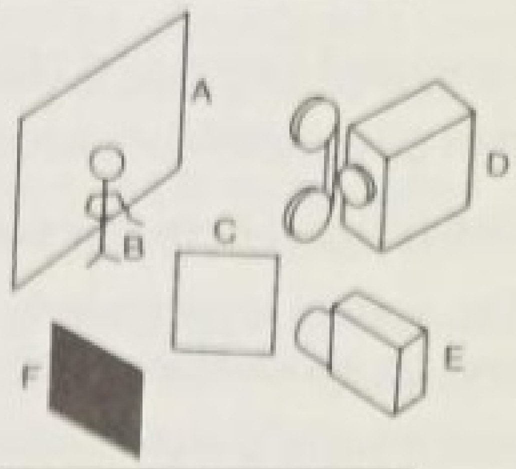
1. Blue screen travelling matte
A. Blue screen;
B. Foreground subject;
C. Foreground camera;
D. Background scene;
E. Background camera;
F. Combined print



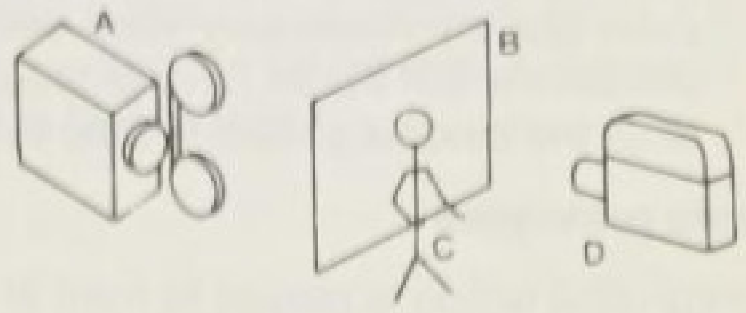
2. Computer manipulated images
A. Film to computer transfer;
B. Computer and computer software program;
C. Computer to film transfer;



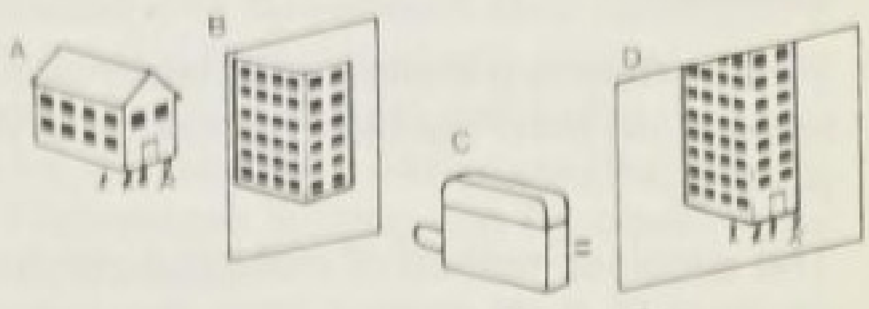
3. Front projection
A. Scotchlite screen;
B. Foreground subject;
C. Semi-silvered mirror;
D. Background projector;
E. Camera;
F. Black baffle



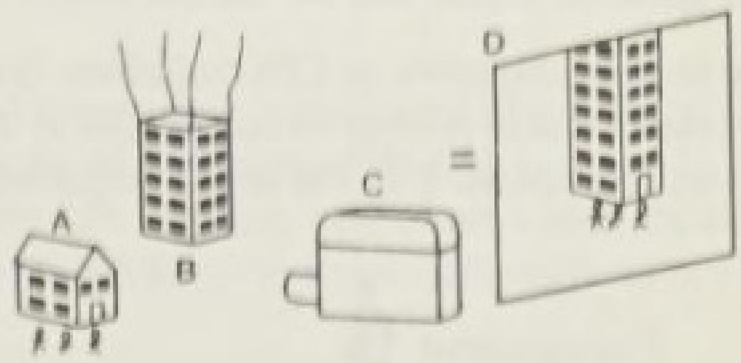
4. Rear projection
A. Projector;
B. Translucent screen;
C. Foreground subject;
D. Camera



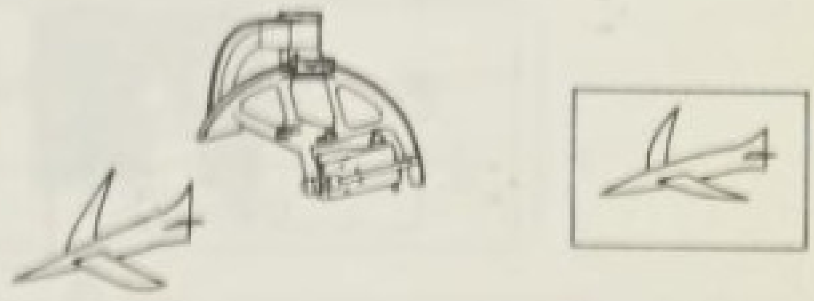
5. Glass shot
A. Background scene of low building;
B. Matching glass painting of upper storeys;
C. Camera;
D. Combined scene



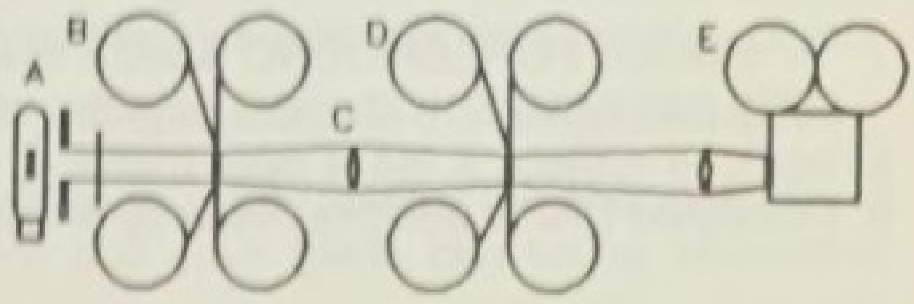
6. Hanging miniatures or scale models
A. Scene of low building;
B. Model of upper storeys;
C. Camera;
D. Combined scene



7. Motion control
A. Camera;
B. Computer controlled camera and camera support;
C. Object 1;
D. Object 2;
E. Combined original negative



8. Optical printing
A. Light source;
B. Film element 1;
C. Aerial image optics;
D. Film element 2;
E. Camera



7.2 BLUE SCREEN TRAVELLING MATTE CINEMATOGRAPHY

Many producers prefer to use blue screen travelling matte or blue cinematography in preference to other process systems for a number of reasons:

Firstly, the quality of the composite image compared to the original is better than by any other method, particularly if a large format (65mm or Vistavision) background plate and optical printer is used.

The system requires a minimum of fuss on the production floor.

Foreground objects can be lit from any angle and any shadows cast on the blue backing can be transferred to the composite picture.

The foreground camera can pan and tilt, dolly and track and go for wide angle shots or close-ups, just so long as such movements fit in with the background.

The 'background' can include the floor.

There is no limit on how large the background can be relative to the foreground. If the foreground is to be very small compared to the background, the foreground can be photographed against a small screen and the remainder of the matte made up of a hand-painted 'garbage matte'.

Unwanted foreground objects, similarly, can be eliminated by junk mattes.

Can be used in conjunction with motion control cinematography.

Can be used to combine live action with animation.

The system is particularly good for 35mm and 65mm formats. With 16mm problems may be encountered with the resolving power and the image steadiness.

And there is a well-established base of knowledge and expertise about the system with many optical houses and many technicians all over the world who are able to carry out the necessary work with a high degree of skill. A few of the legendary practitioners of the art have pioneered techniques which have significantly advanced what the cinema screen is able to portray.

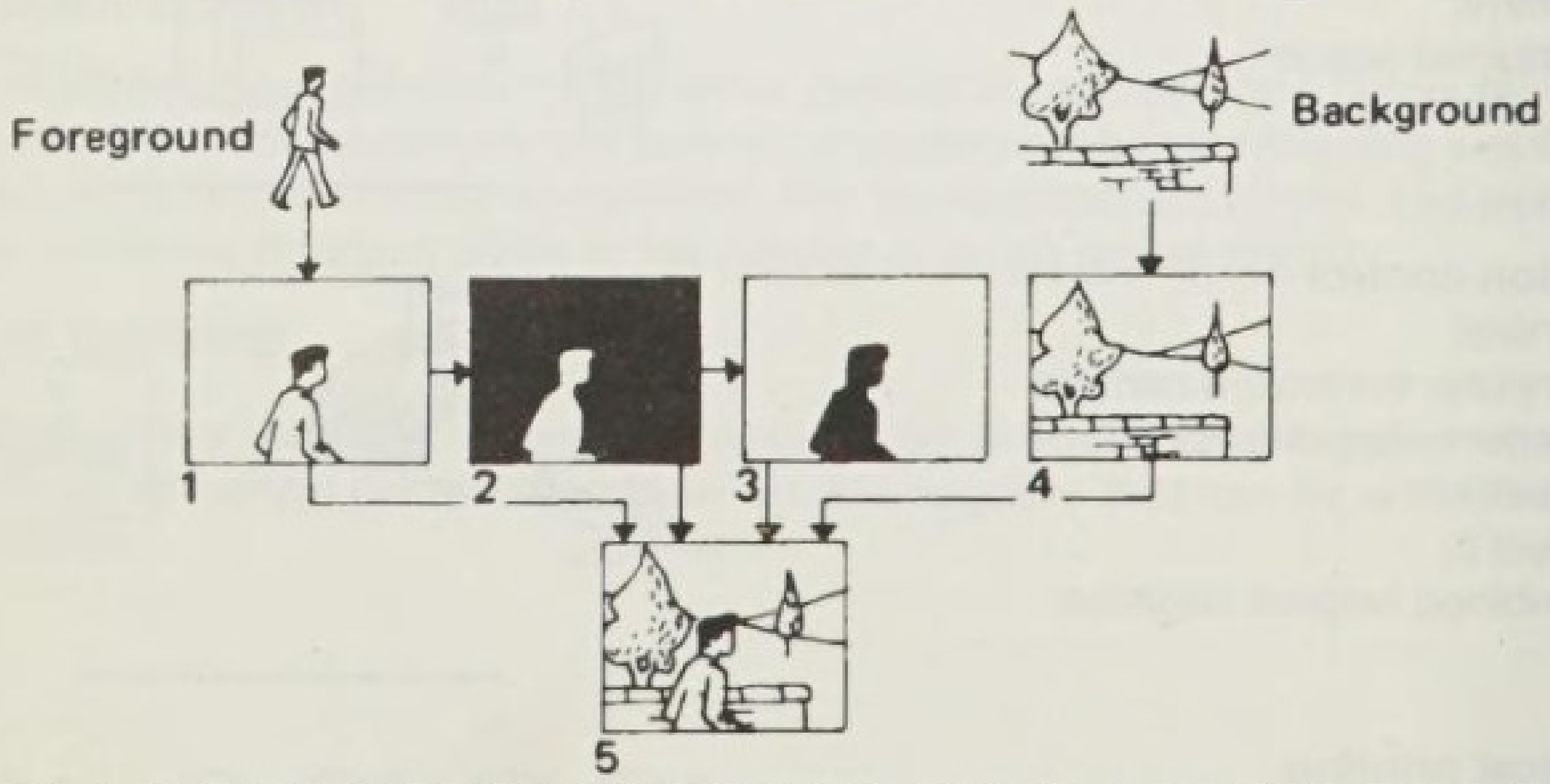
Basic principles

Foreground action is played in front of a plain, brightly lit, blue background screen. Any similar blue coloring or reflections in foreground scenery, props or clothing should be avoided.

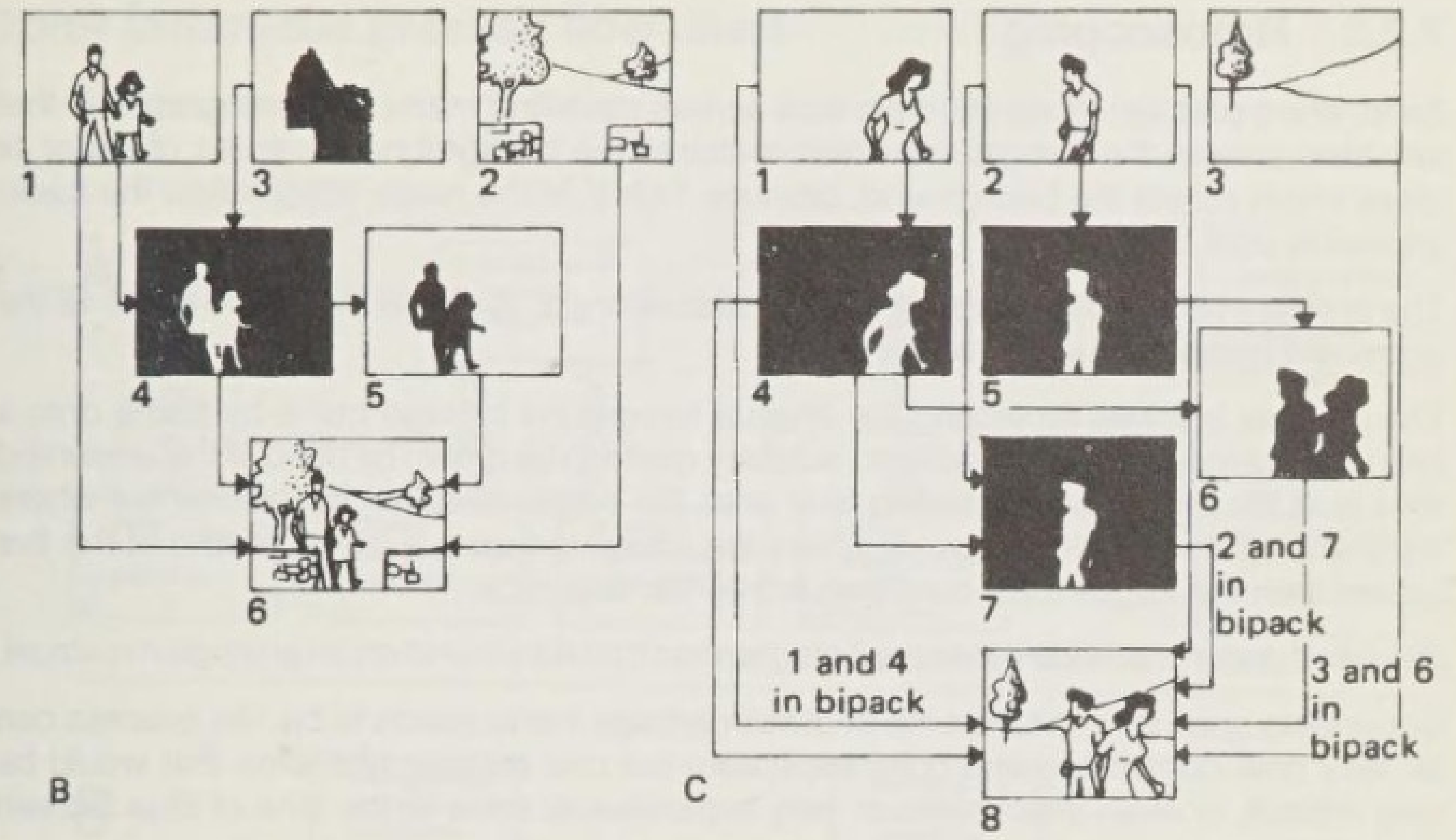
Yellow filters are sometimes placed over the foreground lighting to further separate the foreground from the blue backing, the yellow cast being removed subsequently in the printing.

The simplest method of making a combined negative is to make male and female high contrast B & W mattes from the foreground negative in which the foreground and background areas will be dense black and clear white.

The composite print, or CRI negative, is made by passing the foreground negative through a bipack optical printer in combination with the female matte and repassing it through the printer to expose it to the plate negative in combination with the foreground male matte.



A. SINGLE FOREGROUND IMAGE SUPERIMPOSED IN FRONT OF A BACKGROUND IMAGE: 1. Camera negative of the foreground; 2. B&W female matte of foreground subject; 3. B&W male matte; 4. Camera negative of the background scene; 5. Combined CRI or positive made by printing 1 in bipack with 2 and 4 in bipack with 3.



B. FOREGROUND IMAGE SET BEHIND A SECTION OF BACKGROUND IMAGE: 1. Camera negative of foreground; 2. Camera negative of background scene; 3. Hand-drawn matte around section of background scene; 4. B&W female matte made from foreground negative and auxiliary matte; 5. B&W male matte; 6. Combination print made by printing 1 in bipack with 4 and 2 in bipack with 5.

C. ONE FOREGROUND IMAGE PASSING IN FRONT OF ANOTHER FOREGROUND IMAGE AGAINST A SEPARATE BACKGROUND IMAGE: 1. Camera negative of dominant foreground subject shot against blue backing; 2. Camera negative of secondary foreground subject shot against blue backing; 3. Camera negative of background scene; 4. Female matte of 1; 5. Female matte of 2; 6. Male matte of 4 & 5; 7. Female matte of 2 & 4; 8. Combination print of 1 printed in bipack with 4, 2 printed in bipack with 7, and 3 printed in bipack with 6.

7.2.1 The blue screen

The blue backing may be made of solid material and painted with special paint or it may be made of blue translucent material and illuminated with fluorescent strip lighting or it may be made of a neutral color translucent material and illuminated with special narrow band fluorescent strip lights. These are available 8 ft. and 4 ft. long and in the 420-440 and 430-450 Nm wavebands. Special filter material is available to wrap round fluorescent tubes to control the color of their light output. Fluorescent lighting can be made to be 'flicker-free' by running them off special 10,000 Hz ballasts.

If the screen is a painted one it should be evenly lit by lighting which is of high color temperature.

The color of the screen is critical. It needs to be of a very narrow waveband which coincides with the most sensitive waveband of the blue layer of the color film being used in the foreground action camera. HMI and daylight color arc lighting are often used. Special paints are available. Common practice has shown the following to be optimum colors for the various filmstocks:

Filmstock	Recommended light (Nm)
Eastmancolor 5247	420-440
Fuji 8511	430-450
Gavaert XT125	420-440

Alternatively the screen may be made of front projection material and be illuminated by a special blue lamp projected coaxially with the camera lens.

The blue screen should be at least 10 – 12ft (3 – 31/2m) behind the furthest foreground object to lessen the effects of 'Blue Wrap' caused by blue spill light falling on the subject.

Metal Halide lighting and blue/green filters should be avoided in the foreground lighting.

Camera lens filtration should be done carefully so as not to destroy the optical quality of the blue screen. In particular diffusion filters and color grads can cause separation problems in the optical process.

7.2.2 Rotoscoping

An inherent problem when shooting blue screen travelling matte cinematography is that any blue area in the foreground which matches the background, or areas of water or glass which reflect the background, produce 'holes' in the matte which allow the background to print through.

The problem can be overcome by the use of auxiliary or 'garbage mattes' to cover all the unwanted holes and unwanted items.

The process involves projecting the original foreground footage frame by frame onto a peg type drawing board to enable an auxiliary matte to be drawn by hand. If the unwanted area is in the middle of an existing blue area the edges need not be precise but where the matte abuts the live action, or where the unwanted area is in the middle of the live action, then the edges must be drawn with great accuracy.

The hand drawn mattes are then rephotographed frame by frame on an animation rostrum.

Depending upon how detailed the fit of the garbage matte needs to be, the process can be very time consuming and quite expensive but can remove problems that would be very difficult, or even impossible, or very expensive to solve at the time of Blue Screen photography.

7.2.3 Color difference travelling matte

Another inherent problem with blue screen travelling matte is that unless the color of the blue screen and of the filtering at the optical printer stage is limited to a very narrow waveband, the range of blue tones that can be used in the foreground is very limited.

Many different means of combatting this problem are in use and each optical house has its own tricks which they tend to keep very secret. One such means of restoring blue tones in the foreground is by making a synthetic blue mask known as a 'Color Difference Matte'.

To do this, red and green separations are made in the normal manner. The green separation is then used in a modified manner to make a synthetic blue mask. By this means the blue backing will remain dark but some 'blue' can be introduced into the foreground image to mix with the reds and greens to produce magenta and cyan.

Making a color difference matte

To make a 'color difference matte' the original negative is put into an optical printer in bipack with the green cancellation separation positive and a print made on B&W panchromatic film by blue light, producing an image that is clear except where the green and blue separations differ; hence the name 'Color Difference Matte'.

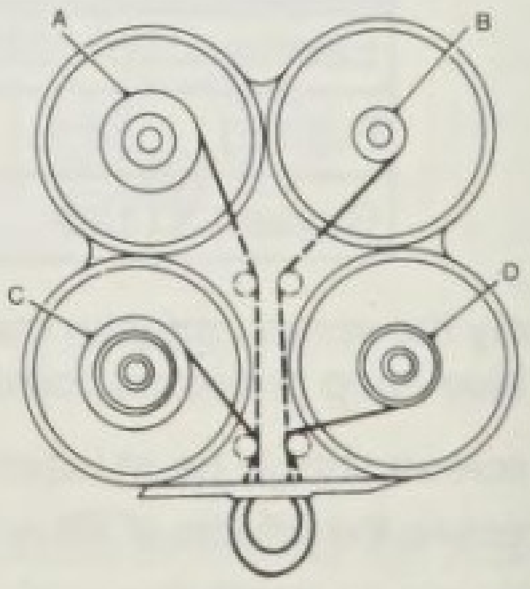
The color difference matte is then bipacked with the green separation to become the 'blue' separation and will reproduce the blue density of yellow and green correctly but with the blue backing dark, rather than light, as would be the case in a normal blue separation.

An alternative method is a combination of blue and green separation onto one piece of film – hence blue–green separation.

To produce the mattes, a special Hi-contrast blue separation is first made from the original. This will have a clear background and a dense foreground. This matte is then printed in bipack with the original negative using a red light and panchromatic film to produce a female matte from which a male matte can then be made.

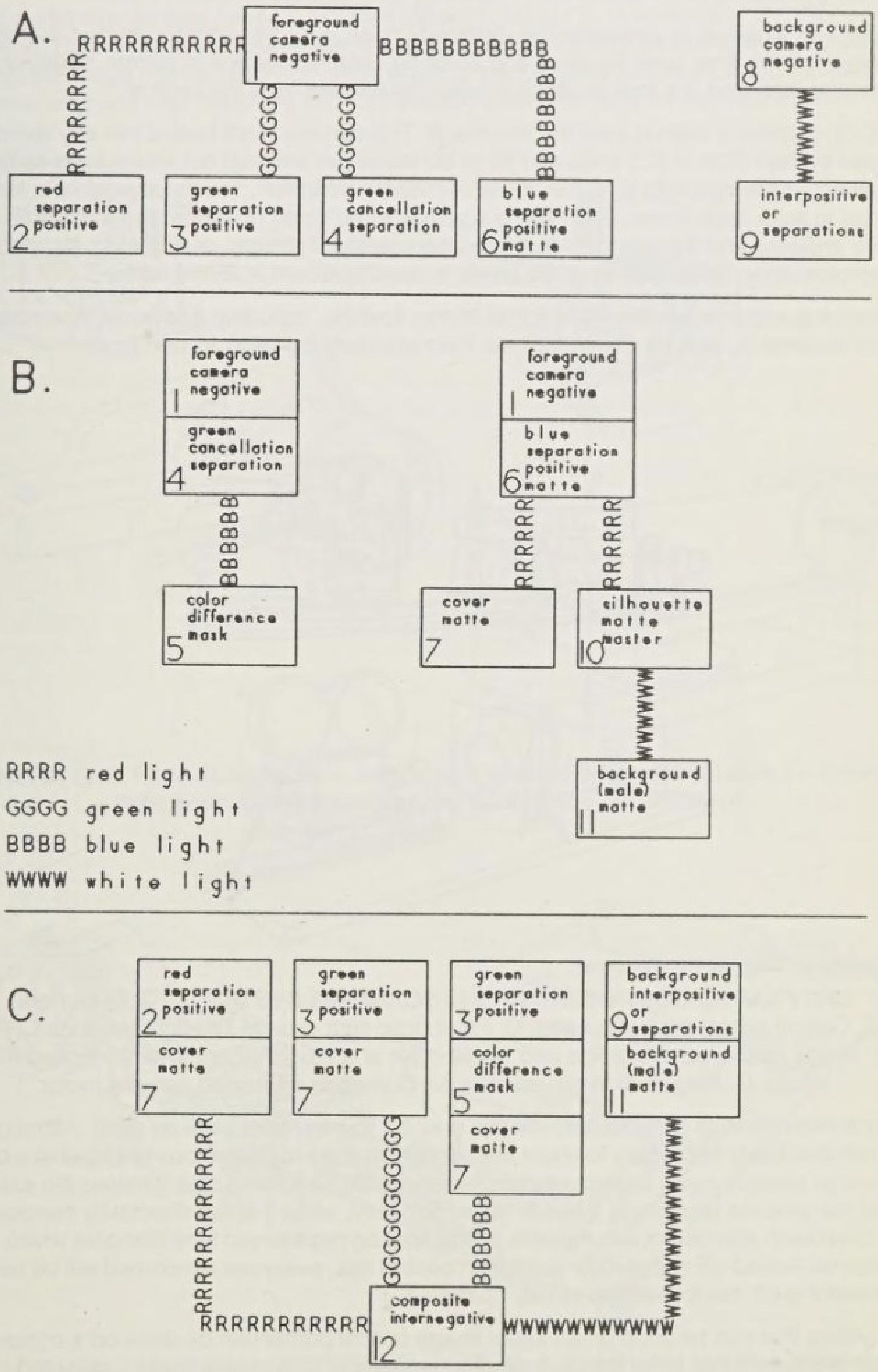
Making the composite negative

To produce the final composite negative the three separations of the foreground image are bipacked in turn with the female matte on an optical printer and printed onto internegative stock. This is then followed by the background separations which are exposed in contact with the male matte.



A BIPACK MAGAZINE: A. Unexposed duplicating filmstock; B. Duplicating filmstock take-up; C. Matte print; D. Matte take-up.

Color Difference process flow chart


A.
RRRRRRRRRRR
foreground camera negative 1
BBBBBBBBBBB
background camera negative 8
GGGGG
GGGGG
WWWWW
red separation positive 2
green separation positive 3
green cancellation separation 4
blue separation positive matte 6
interpositive or separations 9
B.
foreground camera negative 1
green cancellation separation 4
BBBBBB
color difference mask 5
foreground camera negative 1
blue separation positive matte 6
RRRRRR
RRRRRR
cover matte 7
silhouette matte master 10
WWWWW
background (male) matte 11
RRRR red light
GGGG green light
BBBB blue light
WWWW white light
C.
red separation positive 2
cover matte 7
green separation positive 3
cover matte 7
green separation positive 3
color difference mask 5
cover matte 7
background interpositive or separations 9
background (male) matte 11
RRRRRRRRRRRR
GGGGGGGGGGG
BBBBBB
WWWWWWWWWWW
composite internegative 12
RRRRRRRRRRR
WWWWWWWWWWW

Flow chart and system as operated by Roy Field and R.A. Dimbleby
Each rectangle represents a film element, twelve in all, from the original foreground camera negative to the composite internegative.

A. **First stage:** Components made from the foreground and background negatives.

B. **Second stage:** Secondary components made by printing the foreground camera negative in bipack with the first stage components.

C. **Third stage:** Components are combined to create the final composite internegative.

7.3 COMPUTER MANIPULATED IMAGES

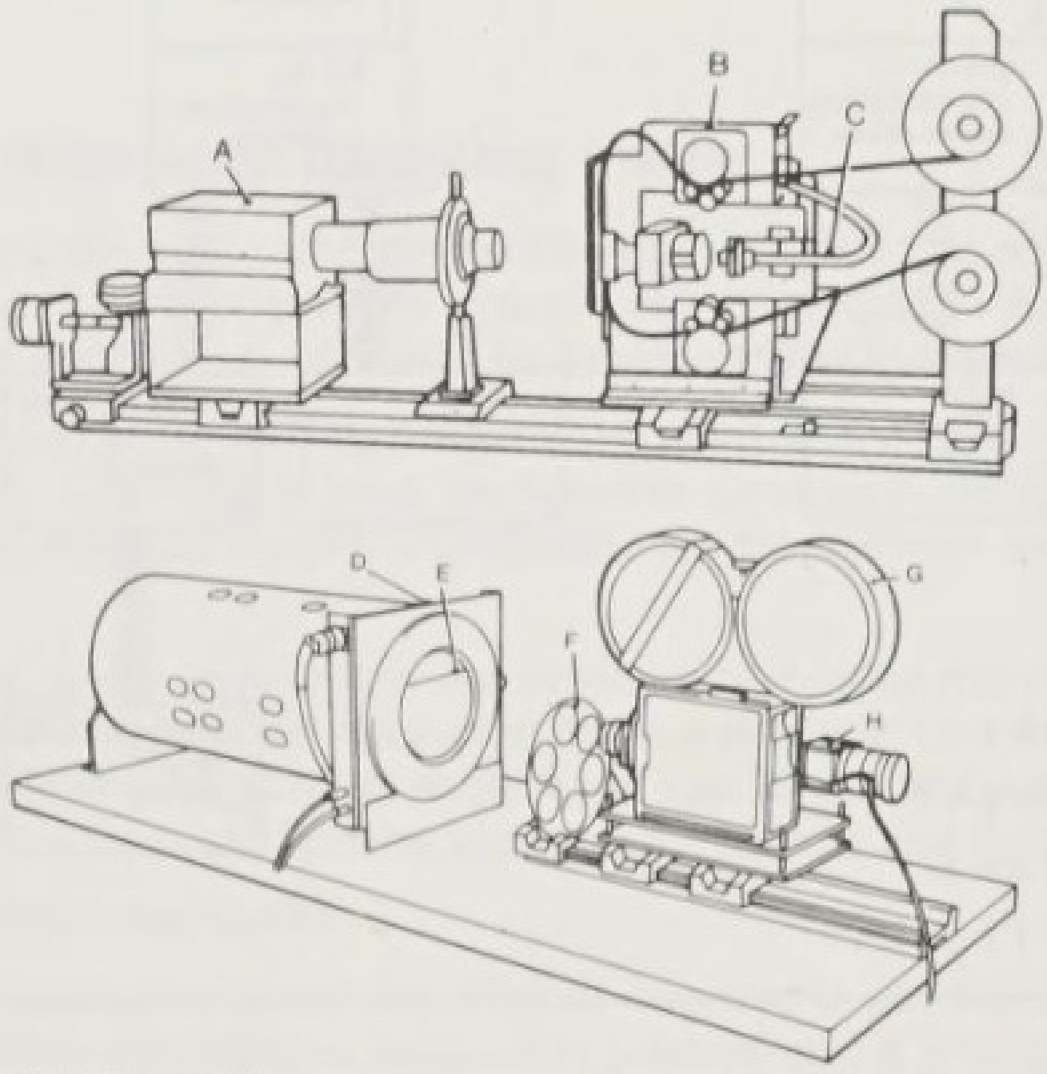
Images photographed on film in a normal manner are transferred digitally to a computer as a series of 'on-off' pixels for each of the red, green and blue records.

Once transferred to computer the image may be manipulated pixel by pixel.

After manipulation is complete the digitized image may be rephotographed, frame by frame, line by line, pixel by pixel and color by color to make a duplicate negative the image quality and the look of which is indistinguishable from the original.

A CCD camera is used to scan the film image. This camera is not locked into any standard video system (525 or 525 lines and 50 or 60 scans per second) but scans lines as finely spaced as are required to achieve the necessary definition, irrespective of how long it takes to scan each frame. Each line is scanned three times (to record the red, green and blue images) and the information stored separately. Typically, a scanning standard of approximately 3000 lines by 4000 pixels is used to record a 35mm frame.

Scanning systems are available for all 35mm formats, including Academy, Anamorphic and Vistavision, and for 65mm formats from standard 5 perf to 15 perf Imax.



(Courtesy the Computer Film Company)

CFC FILM-TO-COMPUTER-TO-FILM SCANNING SYSTEM: A. CCD camera; B. Optical printer projector head; C. Fiber optic light source; D. High definition CRT; E. Image displayed single line and single color at a time; F. Computer controlled filter wheel; G. Registration-pin camera; H. Computer controlled camera motor.

Once committed to a computer, images may be manipulated pixel by pixel. Although it is not absolutely necessary to shoot elements of images to be composited against a blue (or other primary color) background to create a matte from the outset, it makes life easier, and the process less costly if this is done. Similarly, while it is not absolutely necessary to have each element of a composite scene shot on register-pin type cameras which are either on locked-off supports or on motion control rigs, everyone concerned will be better served if such disciplines are strictly observed.

Anything that can be done on an aerial image optical printer can be done on a computer plus any number of other things, including removal of picture elements (unwanted rigs, wires, overhead cables, TV antennas, telegraph poles, hairs in the gate, etc.) and their replacement by adjoining pixels, limited sharpening or defocusing or blurring of images, color correction and compositing of images not shot initially with such a purpose in mind. Scenes can be assembled, layer upon layer, on a high precision video monitor. The layer order can be changed, elements can be changed, the frame synchronization can be changed. Each 'film element' can be treated individually or collectively.

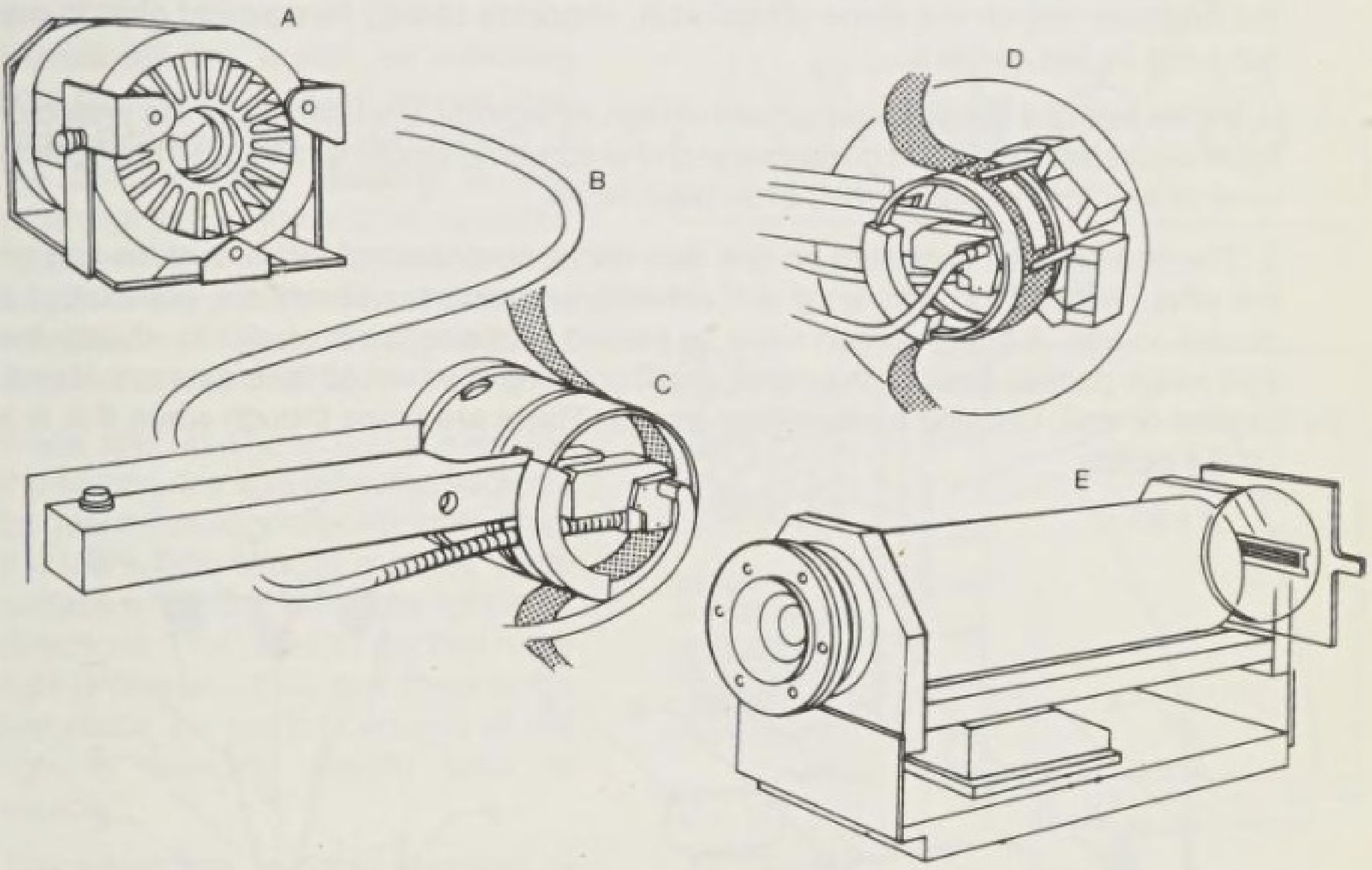
The final composite can be previewed frame by frame, in slow motion or at normal running speed. Any element can be altered, removed, repositioned or modified in any way until it is accepted by the client, after which it is rephotographed, pixel by pixel, line by line and color by color, either from a high precision cathode ray tube (CRT) or by the use of three color matched lasers.

Many computer based effects companies offer specialized services. Some have their own in-house film-to-computer-to-film transfer facilities, others specalise in the computer manipulation of the images and leave the transfer process to others.

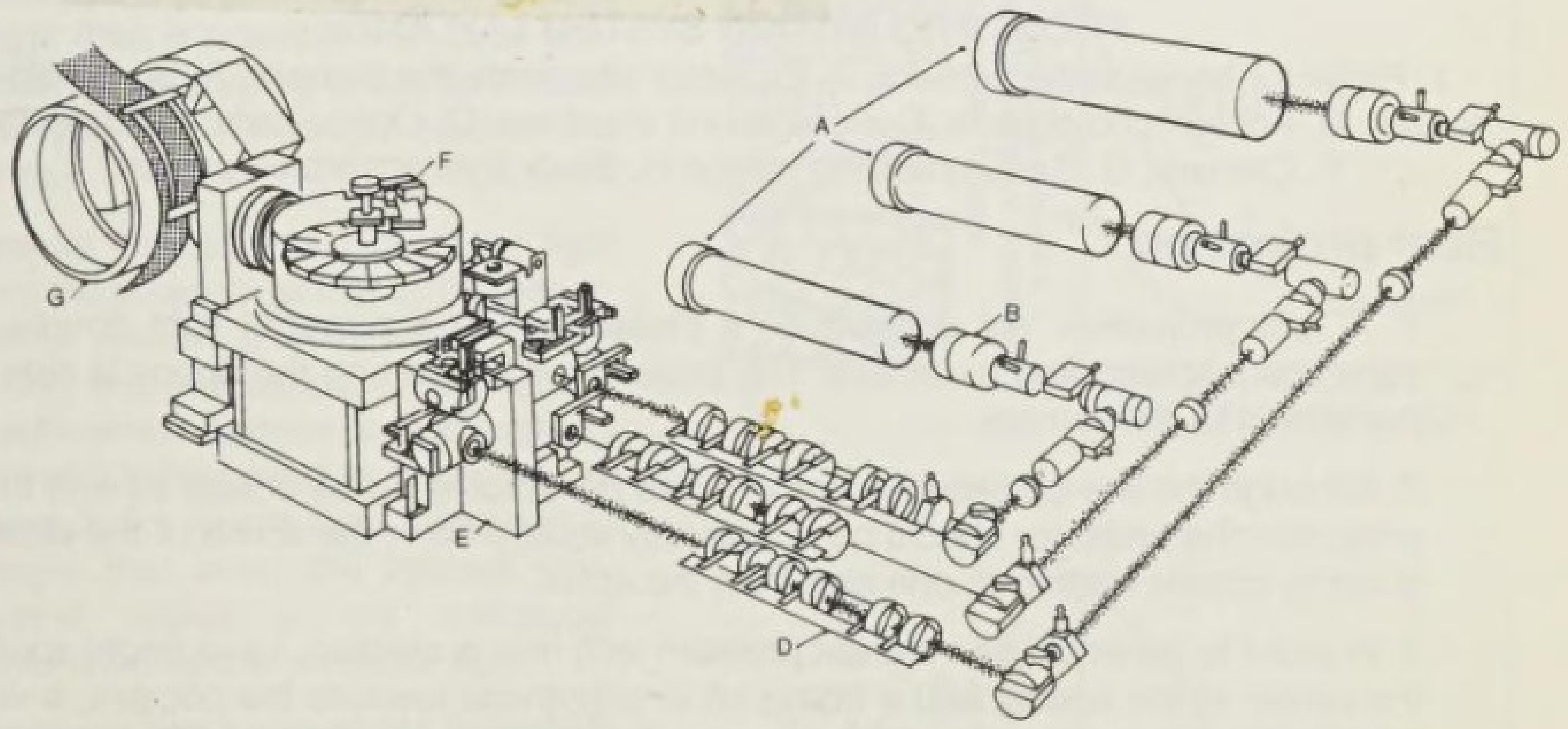
7.3.1 The CINEON(tm) digital film system

The CINEON DIGITAL FILM SYSTEM of the Eastman Kodak company incorporates a film-to-digital scanner and a digital-to-film recorder of unique design, together with the necessary computer hardware and software to use inbetween.

Two digital film centers have been established; CINESITE, Hollywood and CINESITE, London. Elsewhere there are optical houses which have CINEON and other compatible computer image manipulation facilities, sending their original film to a CINESITE facility for scanning and later returning the manipulated computer data for transfer to film.



CINEON CCD FILM SCANNER: A. Xenon light source; B. Liquid light pipe; C. Diffuse light source; D. Register pin film transport; E. CCD sensor.



CINEON LASER FILM RECORDING SYSTEM: A. Green, red and blue lasers; B. Accousto-optical modulators; C. Optical noise eliminators; D. Beam shaper; E. Beam combiner; F. Highspeed polygon; G. Film transport.

7.4 FRONT AND REAR PROJECTION CINEMATOGRAPHY

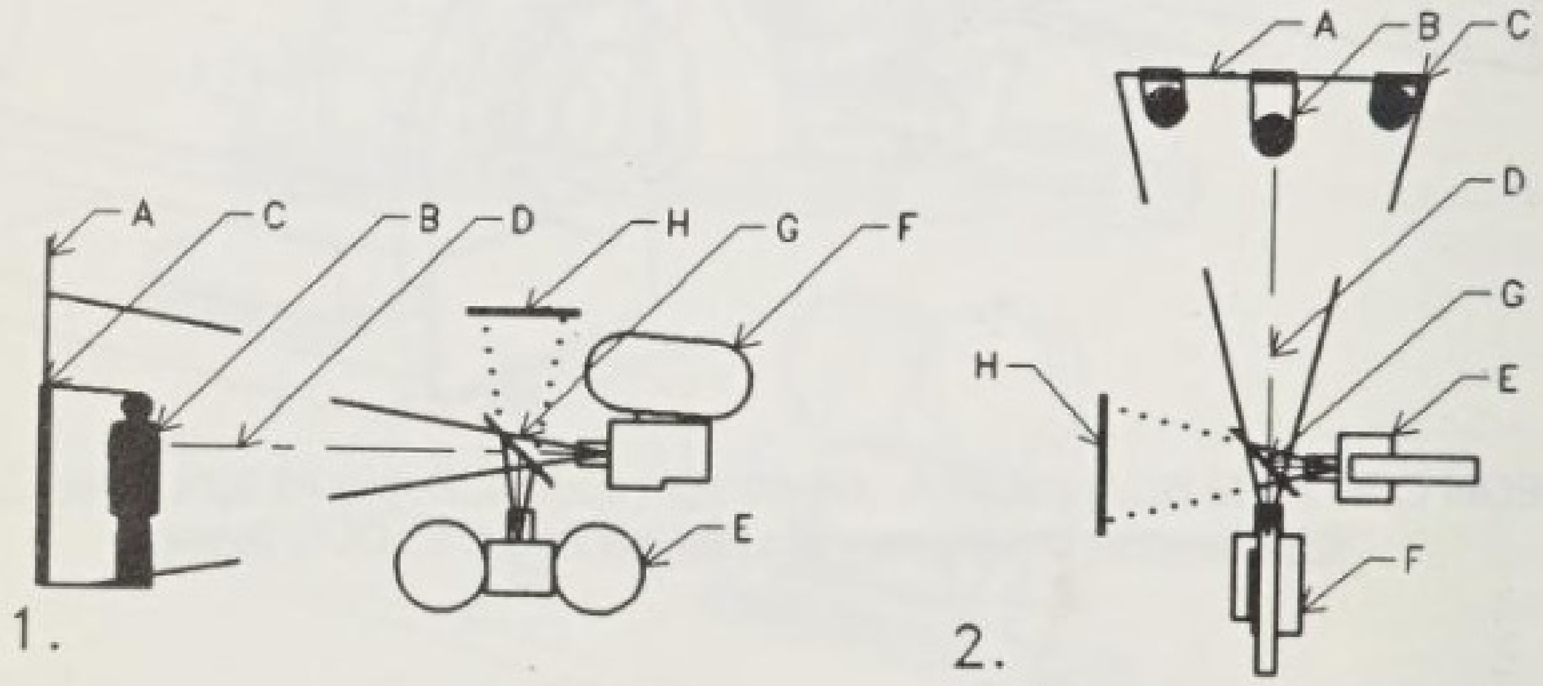
Front Projection

1. A front projection 'rig' consists of a projector, a camera and a beamsplitter mirror arranged in such a manner that the projector and the camera are on exactly the same optical axis. The projector may be located at the side or above or below the camera, in each case the beamsplitter mirror being set at 45° to the optical axis.

2. People and objects may be photographed in front of a screen onto which a background image is being simultaneously projected and because the camera and the projector are on the same optical axis, shadows cast by foreground objects are not seen by the camera.

3. By the use of a background screen of high reflectivity, the intensity of the projector light required to produce a good image on the screen is insufficient to raise the lighting level of any foreground object, even plain white.

4. The beamsplitter is coated on one side with a semisilvered mirror surface and on the other with a high efficiency anti-reflection coating to prevent the creation of a double image. A black screen must be placed opposite the projector to absorb the light which passes through the mirror and if not controlled would illuminate any object, person or wall, causing a secondary image. There are times though when this is a useful facility.



FRONT PROJECTION SYSTEM LAYOUTS:
1. Projector beneath the camera; 2. Projector alongside the camera; A. Scotchlite screen; B. Foreground objects; C. Foreground shadows; D. Optical axis; E. Projector; F. Camera; G. Semi-reflecting mirror; H. Black light absorbing screen

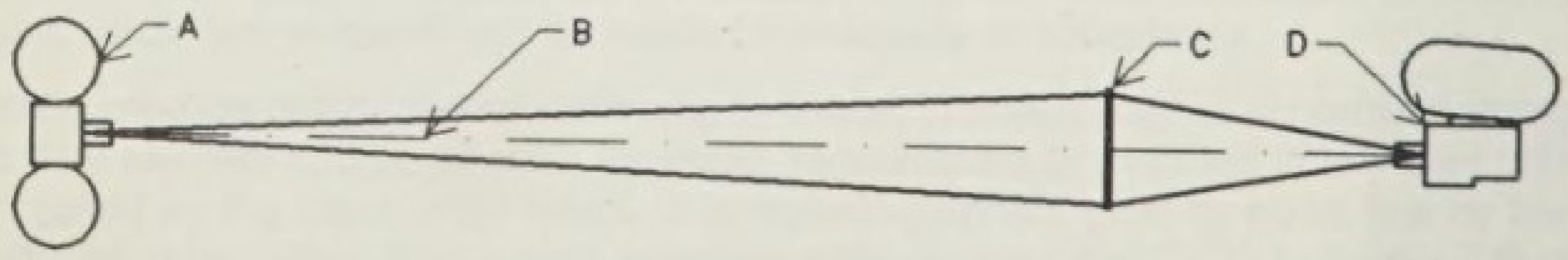
Rear projection

1. A rear projection 'rig' consists of a projector with a powerful light source, a translucent screen and a camera. The projector is located on the opposite side of the screen to the camera.

2. Although the line-up between camera and projector is not as critical as with front projection the projector should be reasonably square-on to the screen if the screen is not to appear darker on one side than the other.

3. In order to minimize an inherent problem with rear projection, i.e. a bright spot in the center of the screen and a falling off in brightness towards the corners, a very long lens must be used on the projector. Focal lengths of 200 - 300mm are not unusual.

4. The camera can be mounted on a dolly or a crane and does not need to remain exactly on the center of the optical axis of the projector.



REAR PROJECTION SYSTEM LAYOUT
A. Back projector with very long focal length lens; B. Optical axis; C. Back projection screen; D. Camera

7.4.1 The Front Projection screen

The product that makes Front Projection process photography practicable is the special screen made of 3M's 'Scotchlite' High Gain Reflective Sheeting. This material is covered on one side with myriad tiny transparent glass beads (approximately a quarter of a million per square inch) which are mirrored over the surface farthest away from the projector/camera and have the property of reflecting light directly back to source. The reverse side of the plastic sheeting is covered with an adhesive backing so that it may be affixed to any support.

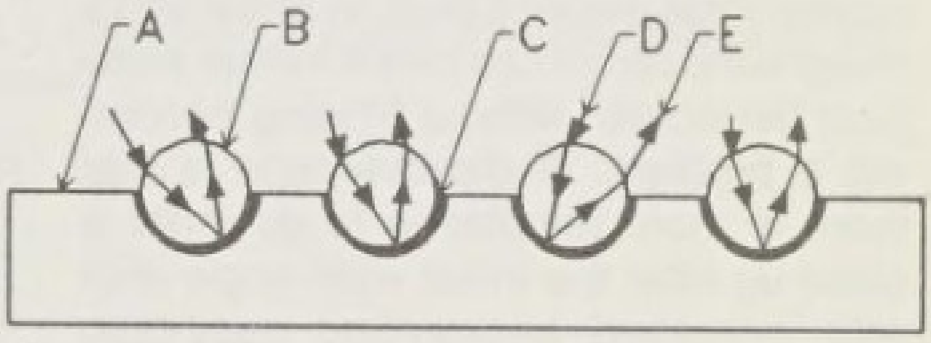
To conceive how the material works, one has to imagine a number of tiny mirrors set into a wall, all reflecting light directly back to the source from which it came. The unique property of the 3M reflective sheeting is that wherever the source of light is situated relative to the material, over a wide angle of incidence, virtually all the reflection off each mirror will go directly back to source.

If one sets up a lamp and shines it at the screen, the light reflected back will be over a thousand times brighter than if it were reflected off a matte white surface which dispersed the light in all directions. This is not to say that more light is reflected than was there in the first place, it is just that virtually all the light is reflected directly back to source.

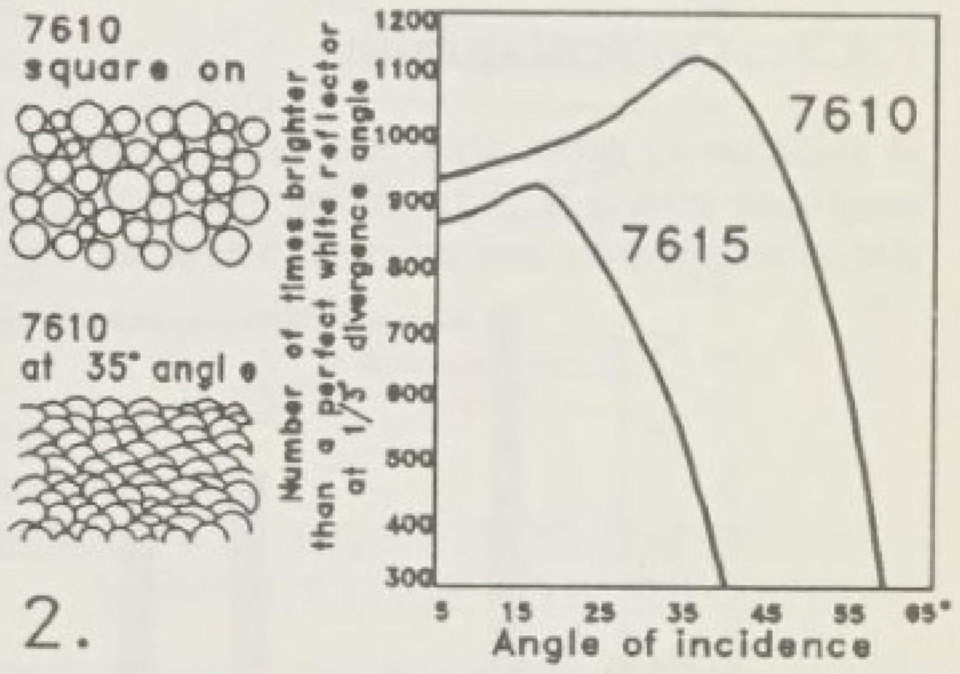
The advantage of using a screen of such high gain is that comparatively little light is required from the projector to illuminate a very large screen, making it possible for a small bulb to illuminate a large screen. (Very much larger than is possible with back projection, even using projectors fitted with powerful xenon or carbon arc lights.)

Despite the fact that 75% of the light from the projector is lost by the beam-splitter system, a level of illumination of only one foot candle on the screen is sufficient to balance foreground key light of 200 foot candles, a net ratio of about 200:1, more than adequate to ensure that even the lightest foreground object is not noticeably illuminated by the projector light.

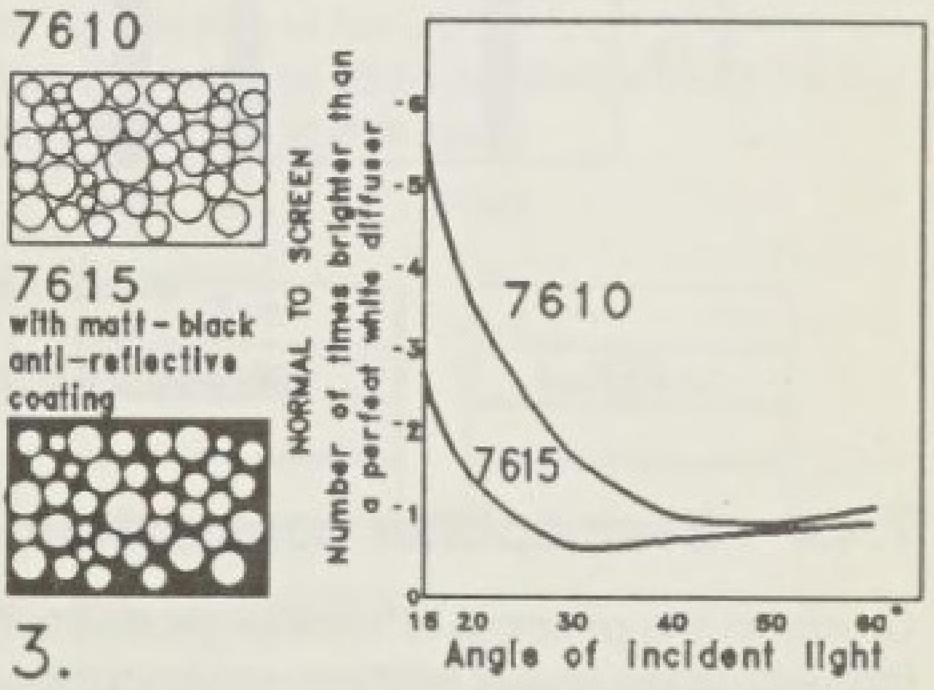
There are two types of 3M Scotchlite used for Front Projection screens. Type 7610, which has a natural color surface to the substrate between the glass beads, and type 7615, which has a black anti-reflective coating between the glass beads. Type 7610 is more efficient in terms of reflectivity but requires that more care be taken to keep stray light from the foreground illumination falling on the background screen. Type 7610 is mostly used in cine work, 7615 for stills photography. There are also retro-reflective fabrics, paint and tape, etc., available.



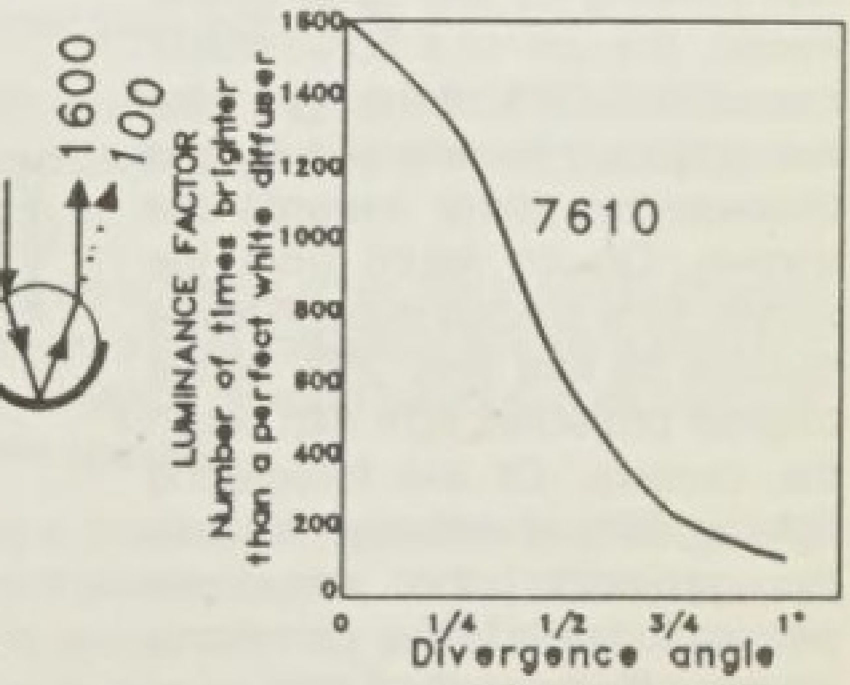
1.



2.



3.



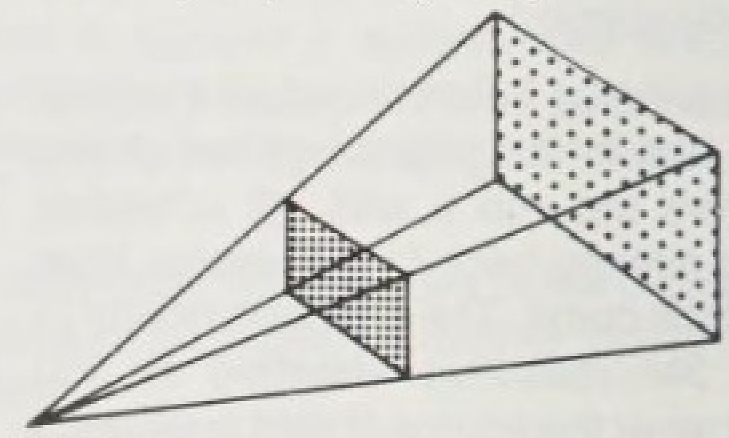
4.

1. SPHERICAL REFLECTORS: A. Plastic substrate; B. Glass beads; C. Mirrored rear surface; D. Light entering; E. Light departing at the same angle; 2. ANGULARITY CURVES; 3. DIFFUSE REFLECTANCE CURVES; 4. DIVERGENCE CURVE

7.4.2 Screen size

Other than that a large screen will require more light from the projector than will a small screen and that it may be more difficult to avoid spill light from the foreground washing out the screen contrast, the size of the background screen makes no difference to image quality so long as the maximum amount of plate image is used and the camera image utilizes the maximum area of the plate, or even extends beyond the screen. Very often, a small screen is useful for close-ups making it more easy to place lighting.

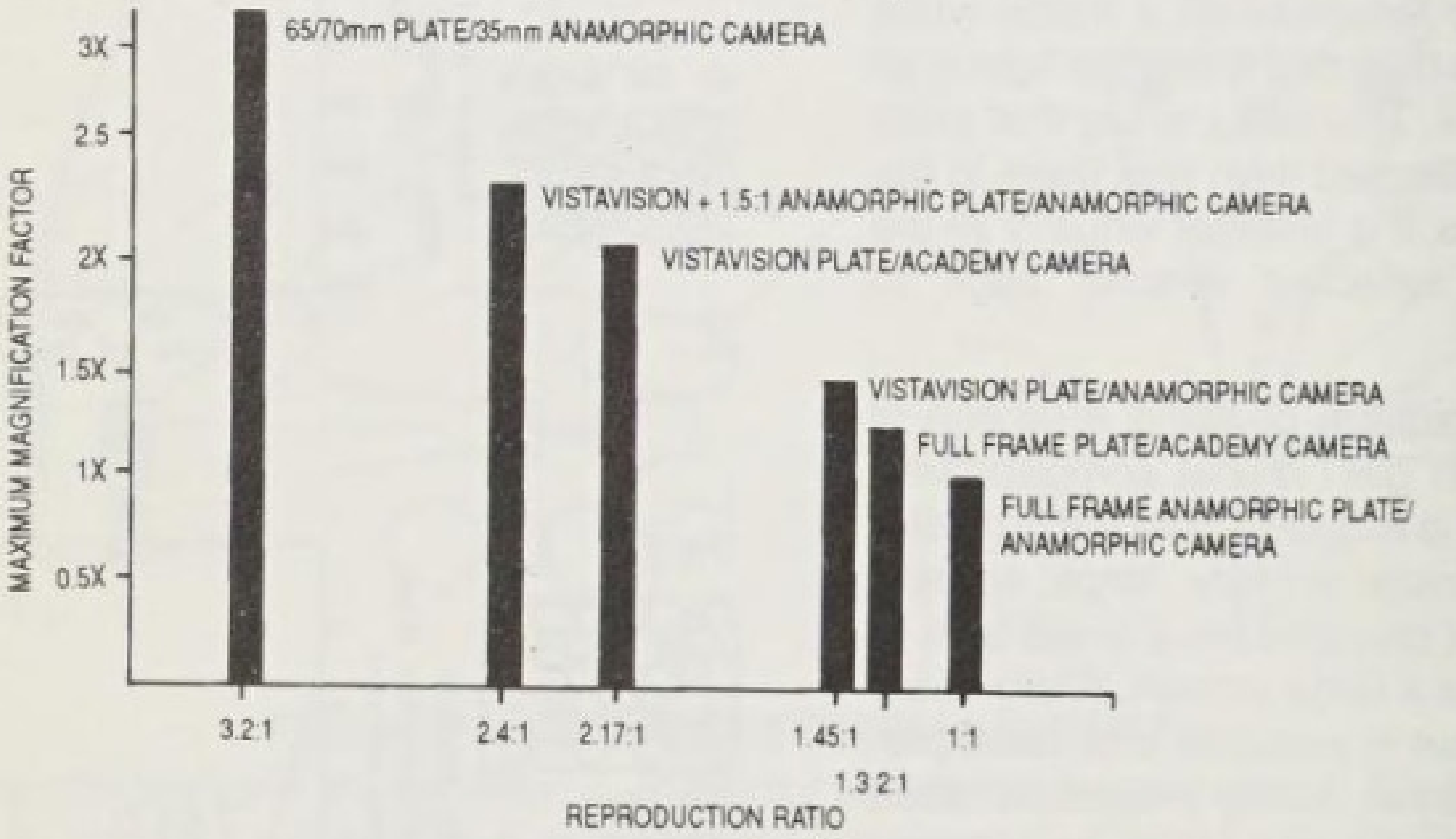
An advantage of a large screen is that any screen joins are less likely to show and a foreground object can be set further away from the screen without fringing becoming a problem. A disadvantage is that there is more temptation to go in for a close-up after the initial wide angle shot with increased background copy-ratio and enlarged grain size.



SCREEN MAGNIFICATION

7.4.3 Optical quality

In addition to grain size, the optical quality of the plate is of great importance. If the projected image is to be more than just a part of the background area then 65mm or Vistavision plates and process projection are to be preferred.

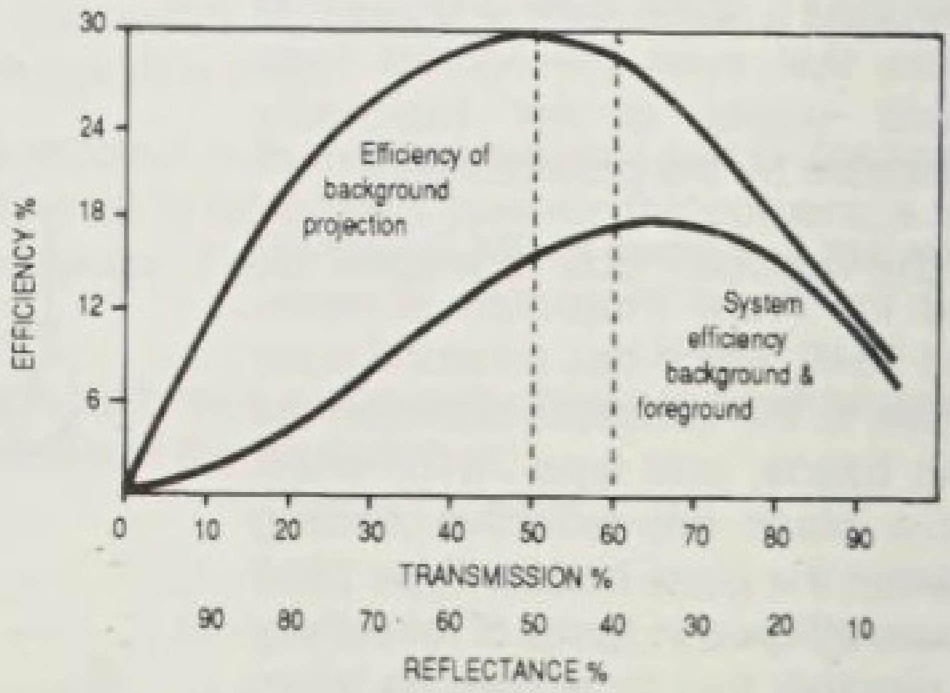


REPRODUCTION RATIO

7.4.4 Beamsplitter considerations

Crucial to the principle of front projection is the use of a beamsplitter to make the point from where the rays of light emerge from the projector lens coincident with the point where the rays of light converge in the camera lens.

Not allowing for any other optical losses, the use of a 50/50 mirror means that 50% of the light from the projector is reflected by the beamsplitter mirror towards the screen. On its return from the screen 50% passes through to the camera so that only 25% of the original projected light can reach the camera. Of the foreground lighting, 50% is reflected towards the projector, the remainder passes through to the camera, a system efficiency of 12.5%.



BEAMSPLITTER R/T EFFICIENCY

In normal practice a 50/50 transmission/reflectance ratio mirror is used for maximum utilization of the projected image but, if the lighting in the foreground and depth of field is at a premium, an increase of the transmission value of the mirror to 60/40 transmission/reflection gives a 12% increase in the utilization of the foreground lighting at a cost of only 4% in the utilization of the projected image. A maximum system efficiency of 14.5% may be achieved by the use of a 65/35 T/R mirror.

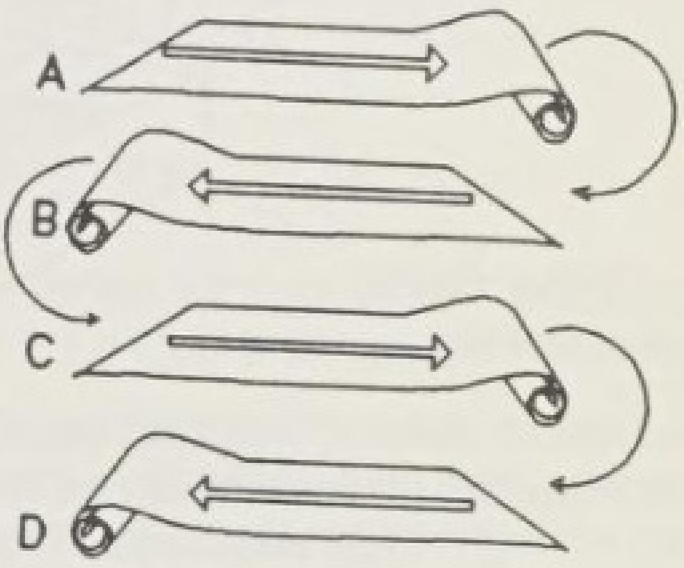
7.4.5 Making up a Front Projection screen

3M 'Scotchlite' Reflective Sheeting may be applied to almost any surface which can be made to be reasonably flat in use, be free of bumps and dents, not stretch and be practicable to handle and suitable for use with the adhesive backing of the screen material.

The size of the screen and the use of reflective sheeting must be pre-planned, taking into consideration the size of the backing required and the manufactured lengths, 2ft wide × 150 (or 300)ft long, of the material.

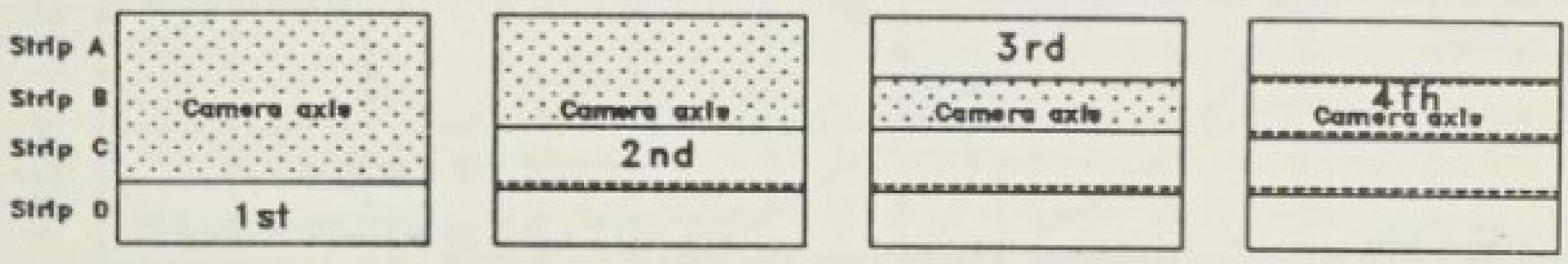
Screens may be made up either by using single strips of material which stretch from one side of the screen to the other or by cutting it into small irregular shaped pieces which are stuck onto the backing in a random manner.

When using the single piece method the material must be applied to the substrate in horizontal strips, in alternate directions with an overlap between strips of about 1/2in (1cm). Horizontal strips are preferable because they are less noticeable on rephotography than vertical or oblique lines, particularly if the shot calls for the camera to pan or dolly across the background screen. Applying in alternate directions ensures that should there be a variation in the reflective characteristics between one side of the roll and the other left-hand edges will adjoin left-hand edges, and right-hand edges adjoin right-hand edges and so on, which will minimize the discrepancy. Overlapping the material by a generous amount eliminates the possibility of strips pulling apart.



UNROLLING METHOD TO PROVIDE CORRECT EDGE TO EDGE MATCH

The layout should be planned so that overlapping layers commence from the bottom and work to the center, or just above, and from the top going downwards with the center section applied last to overlap the layers above and below it. In this way the lens will tend to see less of the edge of each layer, minimizing the risk of horizontal lines showing up. If there is an even number of horizontal strips, the last one to be applied should be the one above center, as this is usually the most critical one at eye level.



SCREEN MOUNTING PROGRESSION

An alternative method of making up a screen is to cut the material into irregular shaped pieces before application to the backing in order to minimize or eliminate the possibility of the joins between pieces of material showing up on the screen. An additional advantage is that small pieces are very much easier to handle than large rolls.

To prevent damage to the glass beads 'Scotchlite' material should not be pressed down too hard especially close to the edges where it is also important to prevent the adhesive being pressed out and showing up or attracting dust.

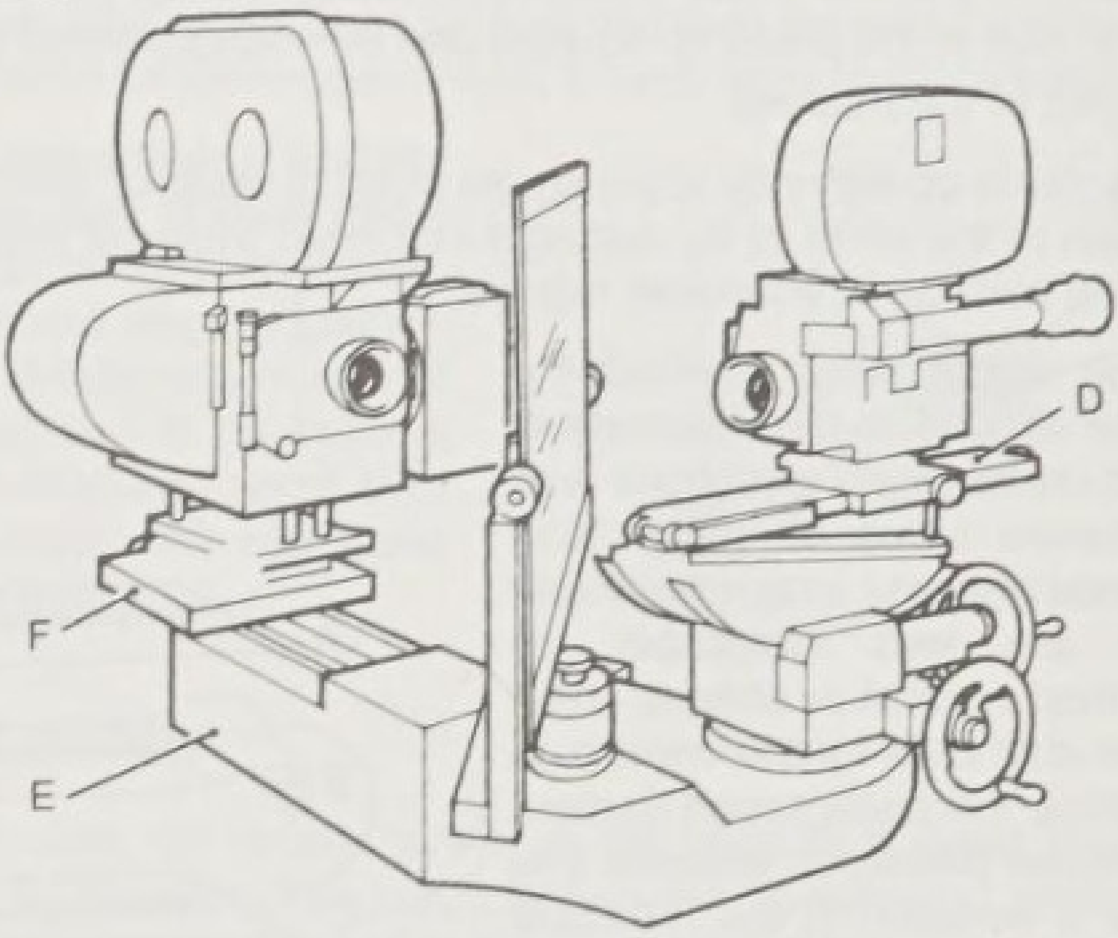
Once completed, standing screens should always be covered when not in use to prevent dust settling. The opening of large studio doors where a front projection screen is standing should be kept to a minimum and if there is any chance of wind blowing dust onto the screen, it should be covered before the doors are opened.

Before using a screen it may be advisable to wipe it down very gently with a damp soft cloth (soap should not be used) to remove any extraneous marks, fingerprints or grease patches that may inadvertently have marred the surface. It may also be necessary to wash down a standing screen from time to time to ensure that it retains its maximum efficiency. Washing a screen can be a frightening experience because at first sight it will look as though irreparable damage has been done. When water is applied it takes on a look of uneven reflectivity which goes away when the surface finally dries off.

Front projection screen material is expensive. It should be treated with care and respect, kept covered when not in use and handled only with gloves.

7.4.6 The Front Projection camera/projector rig

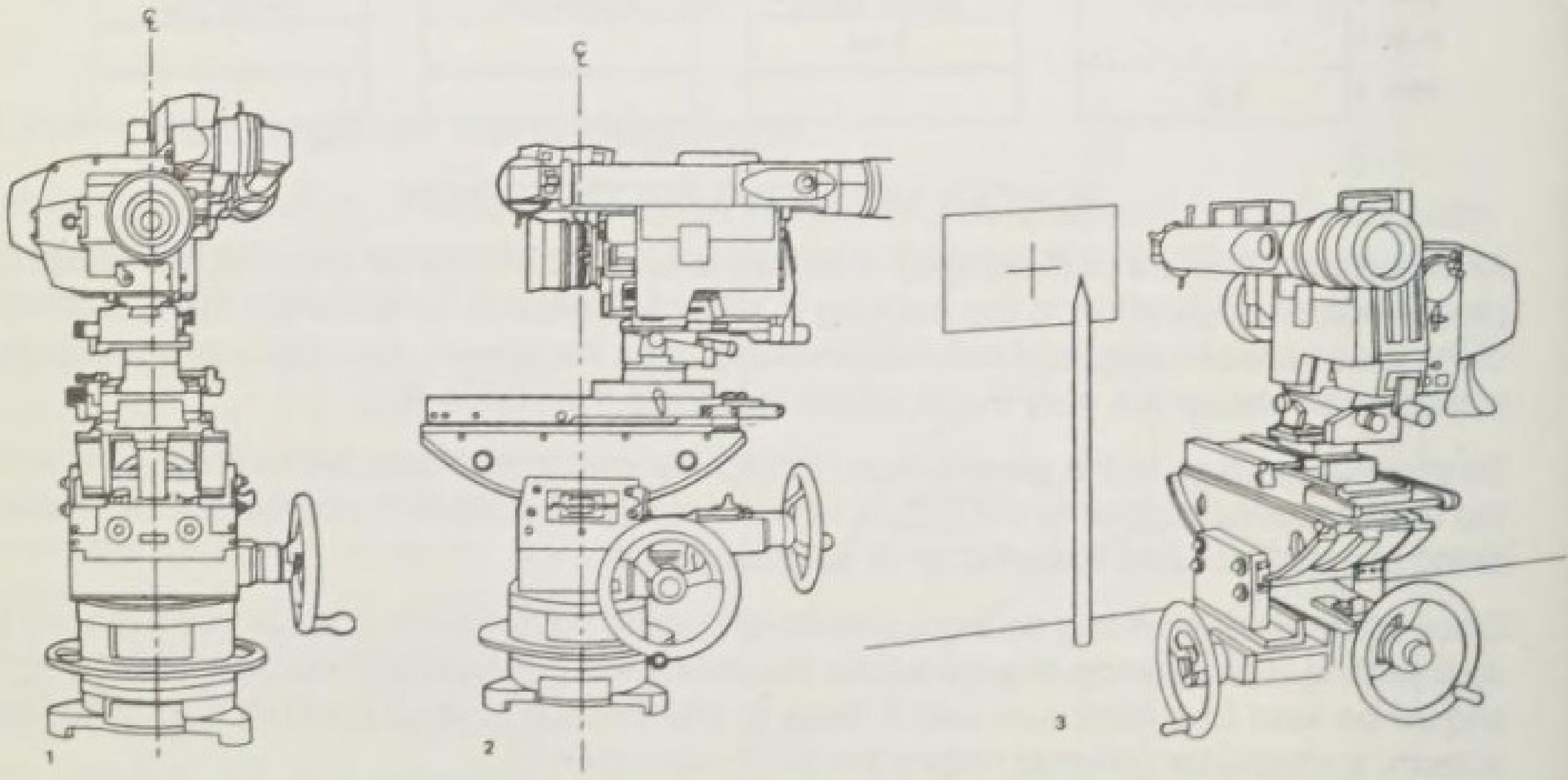
The FP camera/projector rig consists of a camera, a register pin projector and a semi-silvered mirror all precisely and rigidly mounted together as a single unit. The camera and projector must be set at 90° to one another (either horizontally or vertically) and the mirror set at precisely 45° between them.



SAMCINE FRONT PROJECTION RIG
A. Projector (modified Mitchell BNC camera); B. Beamsplitter mirror; C. Camera; D. Nodal adaptor; E. Rigid base; F. Projector micro-adjustment.

The ideal support for the camera is a geared head where the camera can be mounted with the entrance pupil of the lens (the point where all the rays of light entering the lens converge) immediately above the pan axis and in the center of the tilt quadrant. Between the camera and the geared head there needs to be a nodal adaptor which positions the camera correctly and allows micro adjustment side to side and up and down. The balancing slide, which most geared heads have, can usually be used for forwards and backwards adjustment.

The simple way to check if a camera and lens are mounted nodally is to place a pointer on a stand in front of the camera and a cross on the studio wall and line them up through the camera so they are coincident. If the camera and lens are mounted nodally it will be possible to pan and tilt the camera without the pointer and the cross moving relative to one another.



NODAL CAMERA MOUNTING
1. & 2. Panaflex camera set nodally on a Panahead using a Panavision nodal adaptor; 3. A simple way to check nodal alignment.

Either the projector or the head supporting the camera should also have side to side and up and down micro adjustment so the camera and projector can be precisely aligned together once the camera position on the head has been determined. The projector should also be able to be slid back and forth to set the entrance pupil of the projector lens in position relative to the camera lens.

The mirror should be set with the reflective coating towards the projector.

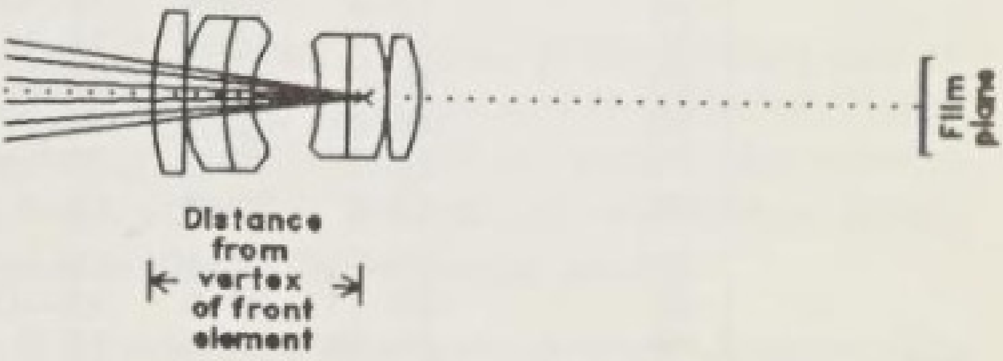
7.4.7 Front Projection camera/projector alignment

To ensure that foreground objects situated in front of a front projection screen completely hide their own shadows from the camera it is crucial that not only are the lenses of both the camera and the projector on an identical optical axis but also that the front nodal points are sited in exactly the same point in space.

The degree of accuracy required to minimize fringing will depend upon how close the subject is to the screen compared to the camera (the closer to the screen the better) how far the screen is away from the camera (the farther the better) and the apertures and focal lengths of the projector and camera lenses (the smaller and shorter the better).

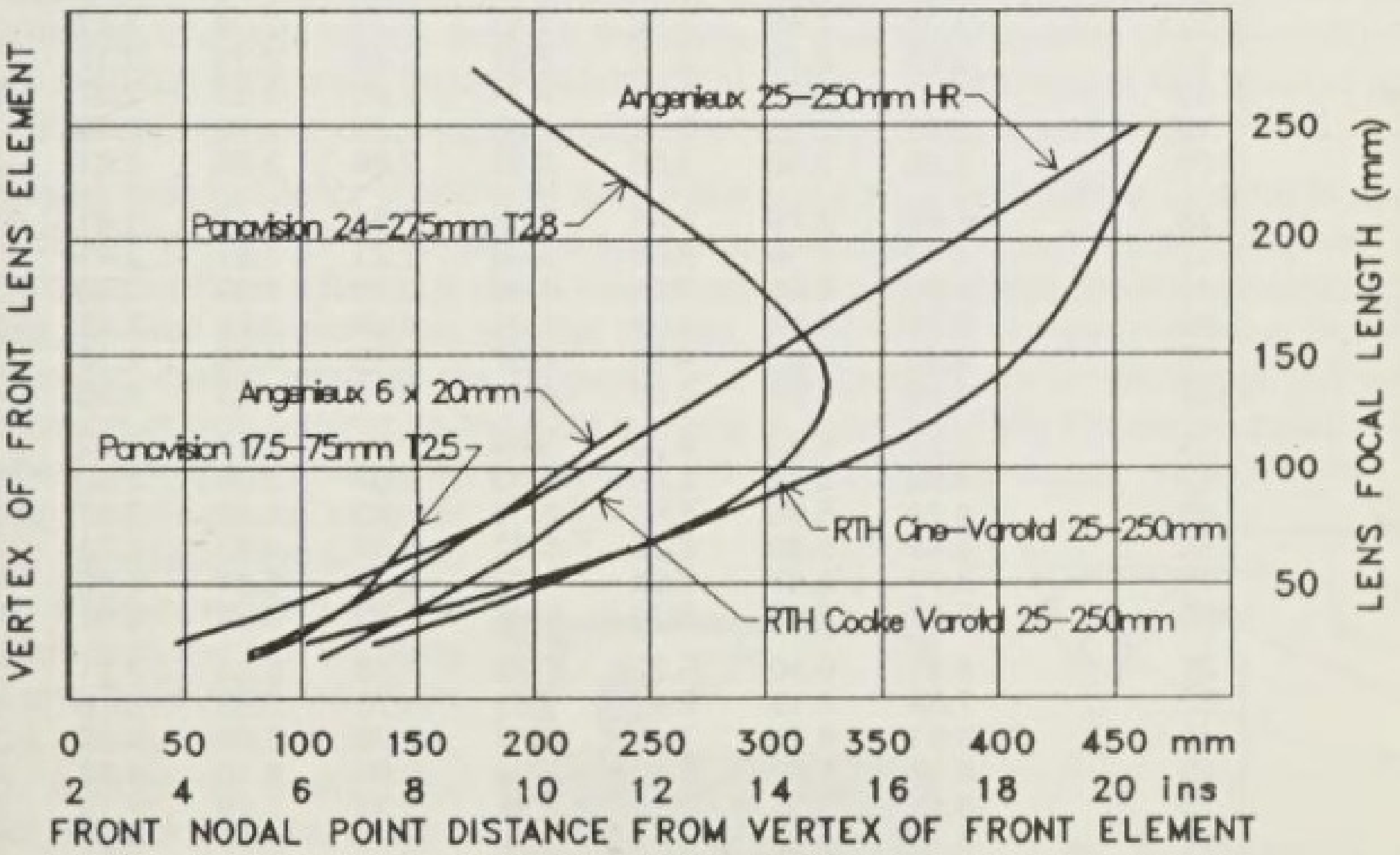
The only exception to this rule is where there is a single, central, foreground object in picture when it is then possible to minimize fringing by placing the front nodal point of the camera lens ahead of the projector exit pupil.

There is no sure way of determining the front nodal point position of any particular lens other than by trial and error tests as described in Section 7.4.6 or by reference to the lens manufacturers. Front nodal points of particular lenses vary widely, even between two lenses of a series by the same manufacturer.



TYPICAL FRONT NODAL POINT POSITION
(100mm T.2.8 Cooke Deep-field Panchro)

With zoom lenses the problem is even greater because the pupil position moves along the optical axis as the focal length is changed. On a typical 35mm type 10:1 zoom lens (Cooke Cine-Varotal) set at infinity the front pupil position is 2in (50mm) behind the vertex of the front element of the lens at the wide angle end, is astride the focal plane at 132mm focal length and is nearly 20in (500mm) behind the front of the lens at the 250mm end of the range, a shift of almost 18 in. (380mm). At close focusing distances the variation is even greater. The Angenieux 6 × 20mm, on the other hand, starts at about 50mm behind the vertex, moves back to about 185mm by the time the focal length is 100mm and then advances to 80mm by the time the lens is at 250mm focal length.



TYPICAL POSITIONS OF ZOOM LENS FRONT NODAL POINTS RELATIVE TO THE FRONT OF THE LENS

Another cause of dark fringing is the fact that the pupils of lenses are not pinpoint in size but have significant diameters, i.e. the diameter of the front pupil of a 100mm lens of f/4 is 25mm, approximately 1 inch.

This halo phenomenon may also be minimized by keeping all the foreground objects as close to the screen as possible, operating with the smallest possible apertures, particularly when shooting close-ups against a light background, and by stopping down the projector more than the camera. Fringing is caused by the sum of misalignment errors of the lenses and the optical halo effect.

The closest it is possible to place a foreground subject relative to the background may be calculated in a similar manner to the near distance calculation of Depth of Field. As with all such calculations, tests should be made to determine what is possible in all the circumstances and what is not. A circle of confusion of 1/1250 (0.02mm) is a good number to start with.

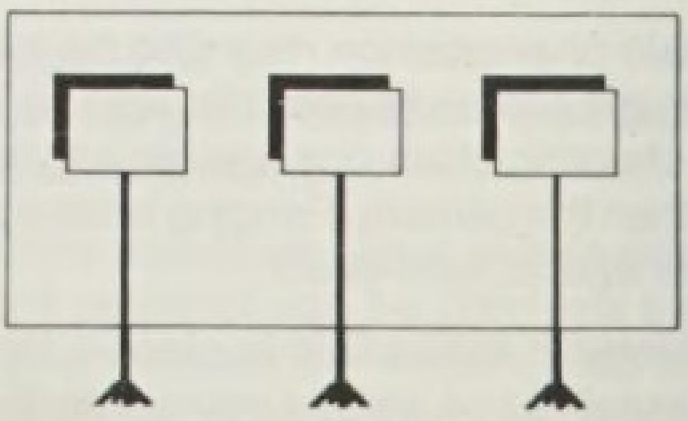
Minimum Object Distance (Feet & Inches)
(Circle of confusion = 0.0008in.)

Screen Distance	Lens Focal Length	Lens Aperture							
		1.4	2.0	2.8	4.0	5.6	8.0	11.0	16.0
10ft	25	8–9	8–4	7–10	7–2	6–5	5–7	4–9	3–10
	32	9–3	8–11	8–7	8–0	7–6	6–8	6–0	5–1
	40	9–6	9–3	9–0	8–8	8–3	7–8	7–0	6–2
	50	9–8	9–6	9–4	9–1	8–9	8–4	7–10	7–2
	75	9–10	9–9	9–8	9–7	9–5	9–2	8–11	8–6
	100	9–11	9–10	9–10	9–9	9–8	9–6	9–4	9–1
15ft	25	12–5	11–7	10–7	9–5	8–2	6–10	5–8	4–5
	32	13–4	12–8	11–11	11–0	9–11	8–8	7–6	6–1
	40	13–10	13–5	12–10	12–2	11–4	10–3	9–2	7–9
	50	14–3	13–11	13–7	13–1	12–5	11–7	10–8	9–5
	75	14–8	14–6	14–4	14–1	13–9	13–3	12–8	11–10
	100	14–9	14–9	14–7	14–5	14–3	13–11	13–7	13–0
20ft	25	15–8	14–4	12–10	11–2	9–6	7–9	6–3	4–9
	32	17–1	16–1	14–11	13–6	11–11	10–2	8–7	6–10
	40	18–0	17–4	16–5	15–3	13–11	12–4	10–10	8–11
	50	18–8	18–10	17–7	16–8	15–8	14–4	12–11	11–2
	75	19–5	19–2	18–10	18–4	17–10	17–0	16–1	14–9
	100	19–8	19–6	19–4	19–0	18–8	18–2	17–7	16–8
30ft	25	21–2	18–10	16–6	13–8	11–3	8–11	6–11	5–2
	32	23–11	22–0	19–10	17–5	14–10	12–3	10–0	7–8
	40	25–10	24–4	22–8	20–6	18–2	15–7	13–2	10–6
	50	27–2	26–1	24–10	23–2	21–2	18–10	16–6	10–6
	75	28–8	28–2	27–5	26–6	25–4	23–9	22–0	19–7
	100	29–2	28–11	28–6	27–11	27–11	26–1	24–11	23–1
45ft	25	26–11	23–10	20–0	16–1	12–10	9–10	7–7	5–6
	32	32–7	29–2	25–6	21–7	17–10	14–2	11–3	8–5
	40	36–2	33–10	30–3	26–6	22–9	18–10	15–5	11–11
	50	38–11	36–10	34–3	31–2	27–8	23–10	20–3	16–2
	75	42–1	40–11	39–6	37–7	35–3	32–3	29–1	25–1
	100	43–4	42–7	41–9	40–6	38–11	36–10	34–5	31–1

Minimum Object Distance (Meters)
(Circle of confusion = 0.02mm)

Screen Distance	Lens Focal Length	Lens Aperture							
		1.4	2.0	2.8	4.0	5.6	8.0	11.0	16.0
3 m	25	2.65	2.52	2.37	2.17	1.95	1.70	1.46	1.18
	32	2.78	2.69	2.58	2.43	2.26	2.04	1.82	1.55
	40	2.85	2.79	2.72	2.61	2.48	2.31	2.12	1.88
	50	2.90	2.86	2.81	2.74	2.65	2.52	2.37	2.17
	75	2.96	2.94	2.91	2.88	2.83	2.76	2.69	2.56
	100	2.98	2.96	2.95	2.93	2.90	2.86	2.81	2.74
5 m	25	4.09	3.79	3.45	3.05	2.64	2.19	1.81	1.40
	32	4.40	4.18	3.93	3.60	3.23	2.81	2.41	1.95
	40	4.60	4.44	4.26	4.00	3.70	3.33	2.96	2.50
	50	4.74	4.63	4.50	4.31	4.09	3.79	3.47	3.05
	75	4.88	4.83	4.76	4.67	4.55	4.38	4.18	3.89
	100	4.93	4.90	4.86	4.81	4.74	4.63	4.50	4.31
7 m	25	5.33	4.83	4.30	3.69	3.11	2.51	2.02	1.53
	32	5.88	5.49	5.06	4.53	3.97	3.34	2.80	2.20
	40	6.24	5.96	5.61	5.19	4.70	4.12	3.57	2.92
	50	6.49	6.30	6.05	5.72	5.33	4.83	4.33	3.69
	75	6.77	6.67	6.54	6.37	6.14	5.84	5.50	5.01
	100	6.87	6.81	6.74	6.63	6.49	6.30	6.07	5.72
10 m	25	6.91	6.10	5.27	4.39	3.58	2.81	2.21	1.63
	32	7.85	7.19	6.47	5.61	4.78	3.90	3.18	2.42
	40	8.51	8.00	7.41	6.67	5.88	5.00	4.21	3.33
	50	8.99	8.62	8.17	7.58	6.90	6.10	5.32	4.39
	75	9.53	9.34	9.10	8.76	8.34	7.79	7.19	6.37
	100	9.73	9.62	9.47	9.30	8.99	8.62	8.20	7.58
15 m	25	8.97	7.65	6.40	5.14	4.07	3.10	2.40	1.73
	32	10.64	9.46	8.24	6.91	5.68	4.49	3.55	2.64
	40	11.88	10.91	9.84	8.57	7.32	6.00	4.90	3.76
	50	12.84	12.01	11.23	10.14	8.97	7.65	6.46	5.14
	75	13.96	13.55	13.05	12.36	11.55	10.51	9.45	8.10
	100	14.40	14.15	13.84	13.39	12.84	12.10	11.28	10.14

Scotchlite covered 'targets' can be used to check and adjust the optical alignment and the amount and direction of any fringing. Set up three 'targets' at the minimum object distance in front of the screen and switch on the projector light without any film in the projector. Any fringing will clearly be seen through the camera. This method is an excellent aid to making final adjustments to the camera/projector alignment.



SCOTCHLITE COVERED TARGETS USED TO CHECK FRINGING

7.4.8 Projector/camera synchronization

For both front and rear projection purposes, the projector, if it is a motion picture one, and the camera must run in perfect shutter synchronization with one another. This may be achieved either by using synchronous motors on both units or by electronic means.

All current camera manufacturers can supply an electronic accessory which will slave their cameras to a projector in exact shutter sync. The equipment consists of an electronic sensor which must be fitted to the projector in close proximity to the shutter or other component which revolves once every frame, and an electronic control box which is situated in-line between the projector and the camera. The system operates by switching out the camera's own internal (crystal) speed control and replacing it with a sync pulse derived from the projector. Both the projector and the camera run off their own power supplies and must be switched on and off independently. Colored warning lights on the electronic unit indicate when the system is running in or out of sync.

The probe should be positioned, and the camera shutter adjusted (if the camera has an adjustable shutter) so that the camera shutter begins to open just as the projector shutter is fully open and is fully closed just as the projector shutter begins to close. In this manner even exposure across the entire frame is ensured. This is particularly important where the camera shutter moves in the opposite direction to the projector shutter.

In an ideal situation, the two shutters should be rotating in the same direction and opening and closing simultaneously to give maximum exposure to the background image. This would mean that with a mirror shutter camera no light would be available to the reflex viewfinder or to the video-assist.

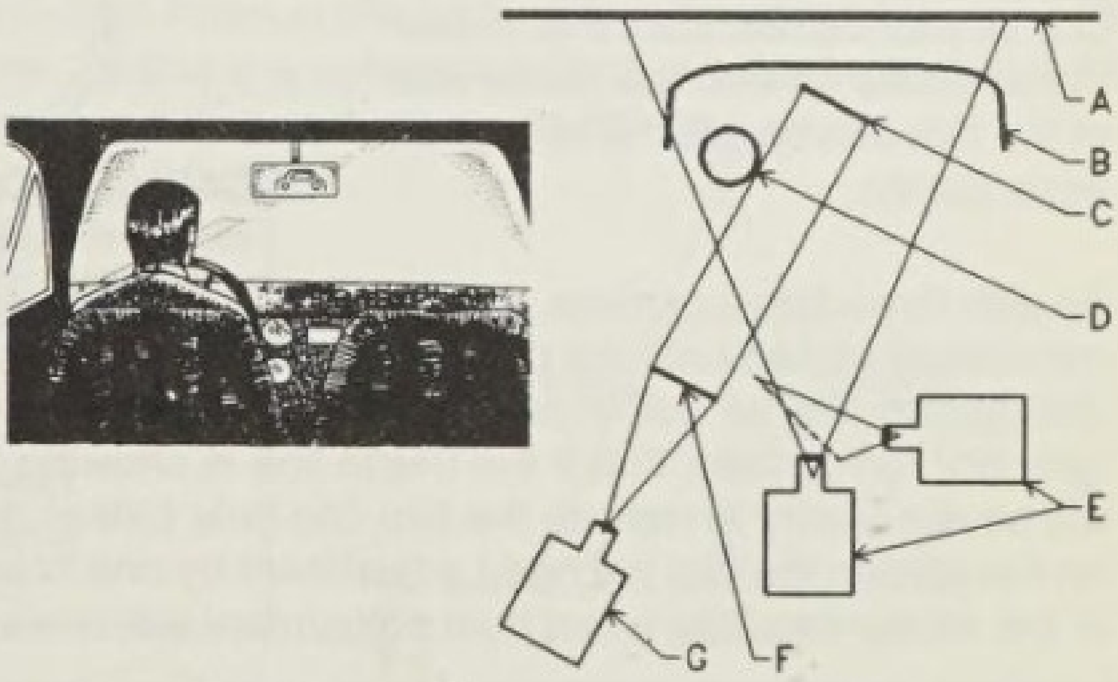
Where circumstances and the projector system permit it may be possible to slip the synchronization point both to balance the foreground and background lighting levels and to provide some light to the viewfinding systems.

Synchronization may be checked by the use of a strobe light accessory to look at first one shutter while it is running and then at the other.

Where both the projector and the camera have crystal controlled motors another way to achieve shutter phase sync is to run both units at the same crystal controlled speed and then use a TV Bar Line Adjustment accessory on the camera to advance the phase until the minimum image is visible through the camera viewfinder system. An even simpler system is to run both units on crystal control at 24fps and flick one or the other to and from 25fps until a minimum image is visible through the camera viewfinder.

If a cinema type projector (fitted with a Maltese cross type intermittent system) is used for process projection photography no special synchronization technique is required as such projectors have a fast pull-down movement and a long dwell period compared to a camera, as well as anti-flicker shutter blades, all of which combine to even out the exposure no matter whether the projector and the camera are in shutter phase synchronization or not, so long as they are running at approximately the same speed. The draw-back is that the images on the screen are not sufficiently steady for static elements in the foreground to be set against a static background image without relative movement between the two showing badly and destroying the whole illusion. They are, however, steady enough for many busy scenes, travelling shots, and for tests and educational purposes.

Cinema type projectors, which do not need to be synchronized with the camera, can also be used to project onto secondary screens which can provide moving reflections on car windows and backward-looking images in rear-view mirrors and will do much to create a look of realism.



USING A COMBINATION OF FRONT AND BACK PROJECTION TO SEE A SECOND IMAGE IN THE DRIVER'S MIRROR: A. FP screen; B. Car windscreen; C. Rear-view mirror; D. Driver; E. FP system; F. BP screen; G. BP projector.

During a Front Projection shoot the camera operator should be aware of how much light from the background image he should expect to see through the mirror shutter viewfinder and report any change or variation in brightness as this will most probably indicate a failure in the synchronization system.

7.4.9 Preparing a projector for front or rear projection

Before commencing to set up a process projection rig and to shoot tests it is useful to have to hand an SMPTE focus test film which can be used to check that the projection is at optimum sharp focus and that the projector light is as even as is possible. If using a camera lens in the projector it may be found that the light distribution is more even at some aperture settings than at others. System image steadiness can be checked by placing a fixed object in front of the screen and observing if there is any relative movement.

A filmed gray scale, together with a hand gray scale similar to the one on the test film, should also be to hand to check color balance.

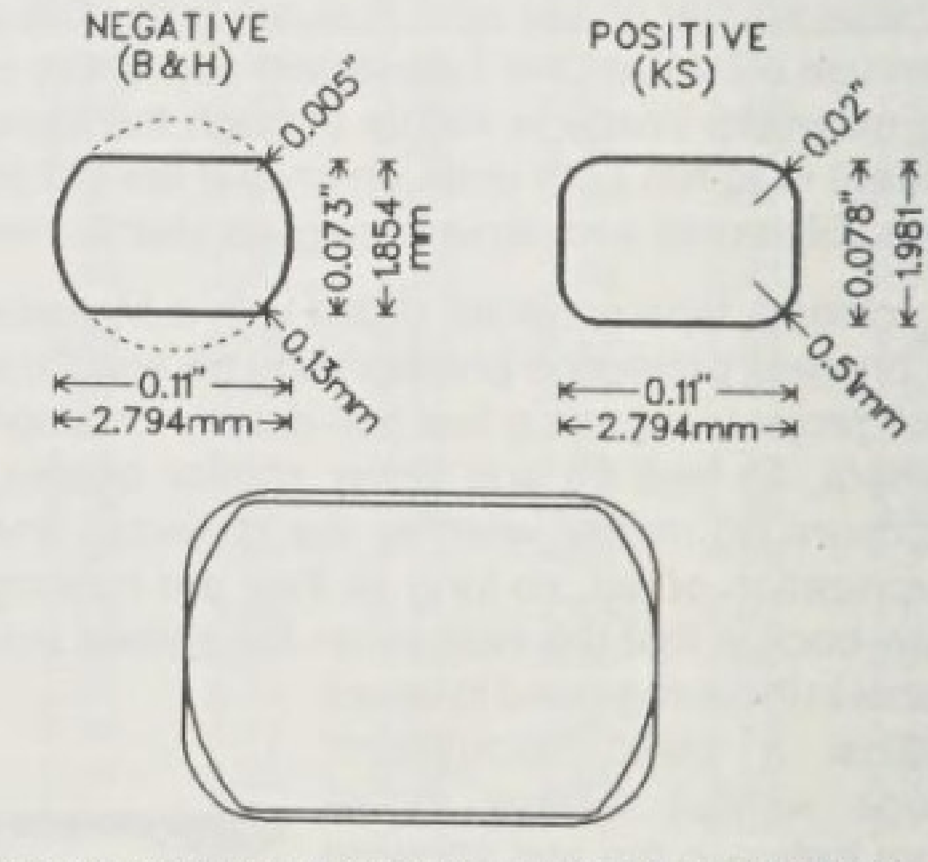
When shooting with a Front Projection rig a matt black screen must be put in position on the opposite side of the beamsplitter from the projector to absorb unrequired light which would otherwise be reflected back into the camera. There are times when this secondary image can be harnessed but these are special techniques.

With either system, the evenness of illumination on the screen must be checked with no film in the projector but with the particular projector lens to be used in position, correctly focused on the screen and stopped down to the working aperture. Note should be taken that the spread of light is even and that there is no objectionable fall-off towards the corners. A central hot-spot is an inherent problem with rear projection which can be minimized by using extremely long focus projection lenses.

If the evenness of the light is not all that it should be, it may be possible to make an improvement by adjusting the relative positions of the lamp filament, the reflector and the condenser. It may even be advantageous to change the condenser lens for one of greater or lesser focal length. If a check on the illumination optical system is required this can simply be done by holding a supplementary lens in front of the projector lens to show on the screen an image of the lamp filament and reflector assembly. The filament should be seen to be central to the reflector. Adjusting the optics of a projector light source is a professional job and should be approached with caution.

It is standard practice to have several prints of each background plate at hand, just in case one or more should be damaged during rehearsals or early takes. In most cases the prints will be specially made on 'negative' perforated filmstock.

The projector must be loaded up in rack, that is to say without the frame line showing during projection. To be able to get it right first time every time it is advantageous to make a mark on the edge of the gate plate one or two frames above or below the aperture so that the frame line of the film can be seen and aligned more easily.



COMPARISON OF 35mm PERFORATION SHAPES AND SIZES

As with threading a camera, the register pin of the projector must be pulled back and the movement inched until the pull-down claws are withdrawn before the film is introduced. Should the film be out of rack when projected, time can be saved on reloading if the operator remembers that if the frame line is showing 3/4 the way up the screen then it will be necessary to replace the film one hole further down. If the rack line is 1/4 the way up the screen the film will need adjustment by one hole upwards in the gate. A frameline in the center requires a two hole adjustment either way.

With a Vistavision projector a frameline to the left of frame means the film must be moved to the right, and vice versa.

Torn perforations must either be repaired with a perforation repair machine or nicked-out. While it is not normal practice to pass a film join through a process projector, film joins made using a tape type joiner, with patches on both sides of the film, may well be found to pass through quite safely.

7.4.10 Background - foreground color matching

The color match of a combined process is subject to many variables:

The color and the color temperature of the lighting of the original subject of the background plate,

The color of the plate print,

The color of the projector light source,

Any color bias of the projector lens and in the case of Front Projection, of the beamsplitter and the front projection screen also.

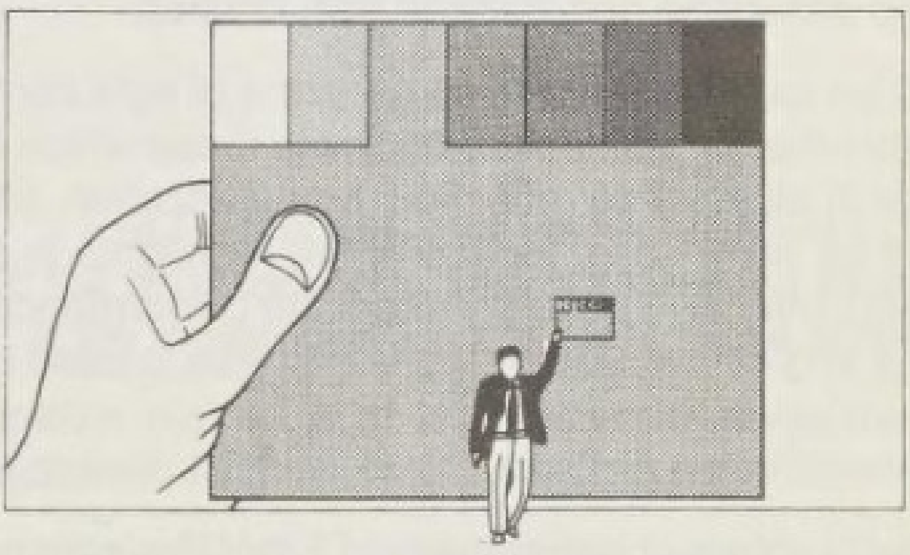
The color of the foreground subject and

The color temperature of the foreground lighting.

Any deviation of the overall color of the combined foreground and background scenes as photographed by the camera is of less importance as this can usually be corrected when the final print is made.

While it is usual practice to have the plates absolutely neutral in color balance it is possible to have them printed with a particular color bias to compensate for any known color bias of the projector light source. In addition the Director of Photography can also be very specific about the overall print density. If there is light in hand with regard to the projector light, the projector lens aperture, the size of the screen and the intended level of foreground lighting, either a full print, with details in all the shadows, or a light print, which will give a brighter background image, may be ordered.

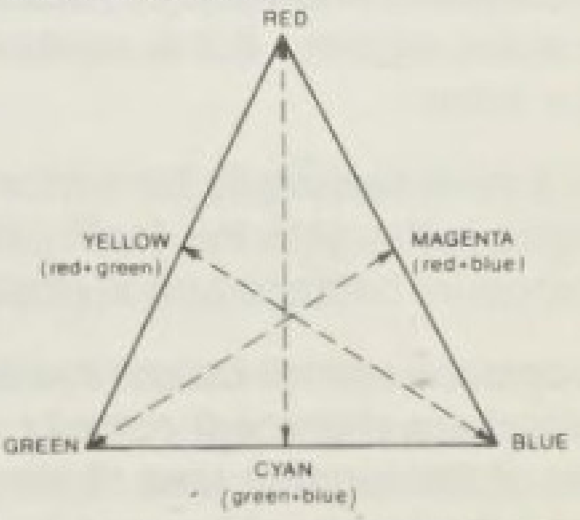
Every projector system (light source, lens, beamsplitter and screen) has its own color bias which must be determined and compensated for. To do this a separate plate must be made of a standard gray scale and projected onto the screen with a similar gray scale, illuminated by the normal set lighting, placed in the foreground. Comparisons can be made and filters placed in the light path of the projector to match the color of the background plate to that of the foreground. A series of tests must then be shot so that the ideal color and density may be made by viewing the combined result on the screen under normal viewing conditions.



COMPARING A PROJECTED GRAY SCALE TO ONE IN THE FOREGROUND

Any imbalance between the color bias of the plate as projected and the foreground as lit must be compensated for either by filtering all the foreground lighting, which may not be practical, or by placing Color Correction filters in the light path of the projector until both gray scales appear to be the same. As this is a subtractive form of color balancing it will be necessary to add opposite colors to make corrections as follows:

Projected Picture	Filter Required
too green	Magenta
too yellow	Blue
too red	Cyan
too magenta	Green
too blue	Yellow
too cyan	Red



It may be necessary to use two adjoining colors, such as red and magenta to achieve a fine balance. The less color correction filtering that can be used the better as some darker types tend to absorb a great deal of light.

It is a frailty of the human optical system that any subjective judgement of the amount of color filtration required to create a natural balance will need to be approximately doubled to be corrected by photography. Thus, if the projected image to the human eye looks to be too green/cyan and a combination of CC10 Red and CC10 Magenta filters is required in the path of the projector light source to compensate, then the chances are that a series of tests can start by centering on CC20R + CC20M.

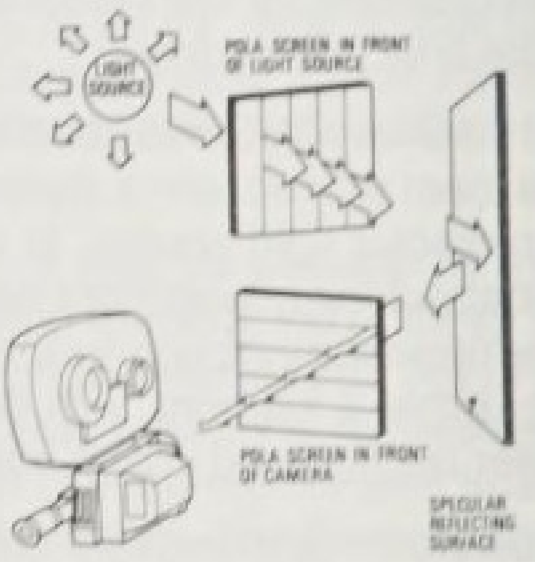
7.4.11 Lighting for front or rear projection cinematography

The most important aspect of lighting the foreground element of a combined front projection scene is that it should blend perfectly with that of the background. The Cinematographer must study the lighting of the background in detail and plan to reproduce it in the foreground.

The direction of the background key light should be noted, together with the direction and amount of fill light, the overall color and look of the plate and any color desaturation and diffusion. In addition to having to match the foreground lighting to that of the background plate the Cinematographer is also constrained by the fact that any foreground light which spills onto the screen will affect the contrast of the projected picture. Whatever is the final 'gray' color of the screen after lighting is complete, that is the deepest black there is going to be in the background plate.

To keep unwanted spill light off the screen barn doors and flags, etc. can be used effectively with fresnel type focusable spot lights. 'Egg crates' and 'honeycomb grids' must be used to control reflector type lamps, soft lights and bounce lighting.

Another means of controlling the foreground lighting is to use polarizing filters on any lights which may cause wash-out problems, especially those that may need to be placed close to the optical axis to match the background lighting. The polarizing filters on the lamps should all be accurately aligned in one direction and a polar screen placed on the camera and accurately lined-up at right-angles to them. The use of polarizing filters on both the lighting and the camera will cause a combined loss of three stops of light. The use of polarized lighting is very tricky and should be approached with caution.


LIGHT SOURCE
POLA SCREEN IN FRONT OF LIGHT SOURCE
POLA SCREEN IN FRONT OF CAMERA
SPECULAR REFLECTING SURFACE

POLAR SCREENS USED TO CONTROL SPILL LIGHT

When using polarizers as a means of light control it should be remembered that the only lights that require polarization are those which would otherwise illuminate the screen and that in eliminating reflection, by polarization, all other reflections off nonmetallic surfaces will be eliminated, including the highlights in the subjects' eyes. The use of polarizing filters may also possibly affect the performance of the beamsplitter of the front projection unit and of the pellicle, if one of these is used in the camera viewfinder system, as these themselves polarize light to a certain extent. Tests should be made beforehand to determine if a problem exists, and if it does to discover the optimum angle of orientation.

The problem of believability in Front Projection shooting can be assisted by the judicious use of image control filters. Diffusers, fogs, nets, low contrast filters, grads and attenuators and smoke all have their place and may be used singly or in combination.

Particularly with Front Projection, anything to do with assessing the balance of the foreground and background lighting and measuring the brightness of the background image for exposure purposes can only be done from the optical axis of the system. Ideally this is done by removing the camera from its mounting on the rig, illuminating a still frame in the projector and taking measurements with a spot meter placed exactly on the nodal point of the system. If this method is possible then accurate exposure measurements may be taken.

If the camera can easily be removed from the rig and the projector left illuminated with a still frame in the gate this facility can also be used to take a Polaroid shot to check color and exposure balance and to place a normal stills camera in position for production stills.

If the camera cannot be removed from the rig without fear of upsetting the critical projector/camera alignment a mirror may be put in the light path, at 45° to the optical axis, in front of the camera lens. It may even be possible to place the exposure meter itself between the beamsplitter and the camera lens.

If the projector cannot show a still frame then it will be necessary to take a reading with the projector running and to shoot tests which must be processed and viewed before any actual shooting is contemplated to determine the performance of any particular type of exposure meter under these circumstances. This is because a running projector emits a square wave-form light which affects different exposure meters in different ways. Once a cinematographer has made a number of tests in this manner with a particular meter it will become possible to calculate exposures in the normal manner, taking any variation into consideration.

7.4.12 Advanced Front Projection techniques

Over the years many means to enhance the basic Front Projection system, or to use it to create some special effect or other, have been developed and used on various pictures. Some of these systems have been developed by individuals or companies who hold proprietary rights to their usage.

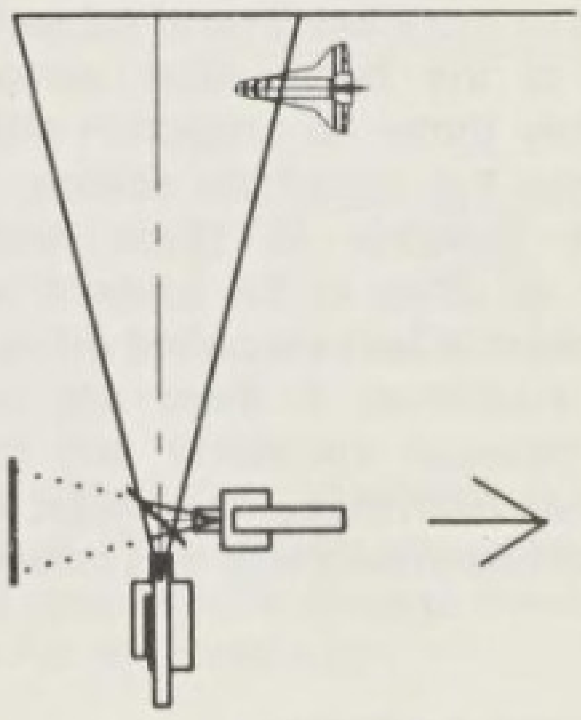
Contrast control

Too much contrast is an often present problem with front projection. To minimize contrast prints made on low-contrast stock are often used. Providing the screen is not too large the contrast of the projected image can also be controlled by stretching a seamless black netting or voile across the background screen. This reduces light scatter and increases the black content of the background.

Projector/camera movement

With the projector/camera system assembled together as a single unit they can be mounted on a dolly or crane and panned and tilted or dollied and tracked, or even rotated, relative to the foreground subject. In all instances the background will appear to remain static and the movement will affect only the foreground. Even if the rig is tracked towards and away from the screen, the background will always remain a constant size and only the foreground will change.

This means that cars, ships and aircraft can be made to move relative to the background and relative to the 'frame' without actually moving. Not only can they move from side to side, but up and down, rotate, come closer and recede, while all the time the background remains constant. All that is required is a suitable mounting system for the rig and a large enough screen so that no matter where the object is viewed from, there will always be screen behind. In such cases the movement on the screen will always appear to be in the opposite direction to the movement of the rig.



PROJECTOR/CAMERA MOVEMENT
If the rig is moved to the right the fixed model in the foreground will appear to move to the left.

Tricks with retro-reflective screen material

Doorways, arches and other openings may be cut in the background screen and foreground subjects made to pass through the background. Hard edged background objects, like buildings or trees or walls, can be made as cut-outs, covered with screen material, and placed some distance in front of the background screen so that people, or animals, in the foreground can pass behind them.

Patches of screen material may be fixed to foreground objects so that the background can be seen 'through' them, making them appear to have holes or windows in them. Care has to be taken when using supplementary screens not to place them too far in front of the background screen or they will appear to be much brighter unless dulled down with dulling spray or other means.

Clothing can be made of retro-reflective material and have images projected on them. If all that is wanted is clothing which is intensely bright then it need only be illuminated by a light box and beamsplitter mirror placed in front of the camera lens.

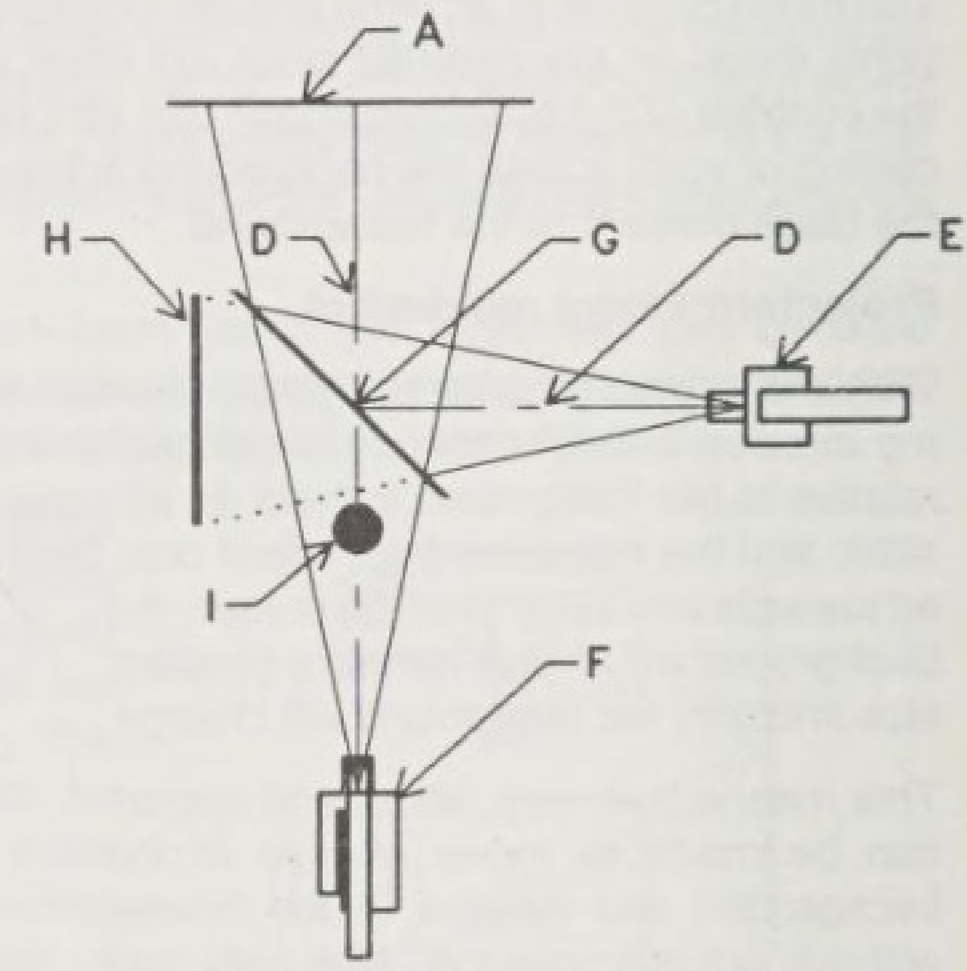
Patches of retro-reflective material, including the various colored 'non-photographic' materials and paint that are available, can be used to provide lights in the windows of empty buildings or miniatures, or anywhere else where a light source should be but which cannot otherwise be achieved. Retro-reflective material has even been known to be stuck on the backs of glasses of beer, in beer commercials, to make the beer look bright and sparkling. In all these cases illumination is achieved by a light box in front of the lens.

Reverse Front Projection

One of the inherent problems with the normal system of Front Projection process photography is that there is a definite limit on how close to the camera a foreground subject can be, relative to the screen, without fringing becoming an insurmountable problem. This limits the use of FP for close-ups and for miniatures where it would otherwise be very useful. The problem was overcome by a system called 'Reverse Front Projection' developed by Apogee Inc. in California.

The system uses a very large sheet of plate glass, or a stretched membrane, as the beamsplitter mirror, allowing projector and the camera to be placed much further apart and for foreground subjects to be placed *in front of the mirror* as well as behind. The limitation on the system becomes the size of the sheet of glass.

With one or more foreground subjects in front of the beamsplitter mirror, where they throw no projection shadows onto the Scotchlite screen, it becomes possible to place such subjects as close to the camera as normal depth of field will permit without fringing problems. If there are no objects between the mirror and the screen then even the camera/projector alignment becomes a little less critical.

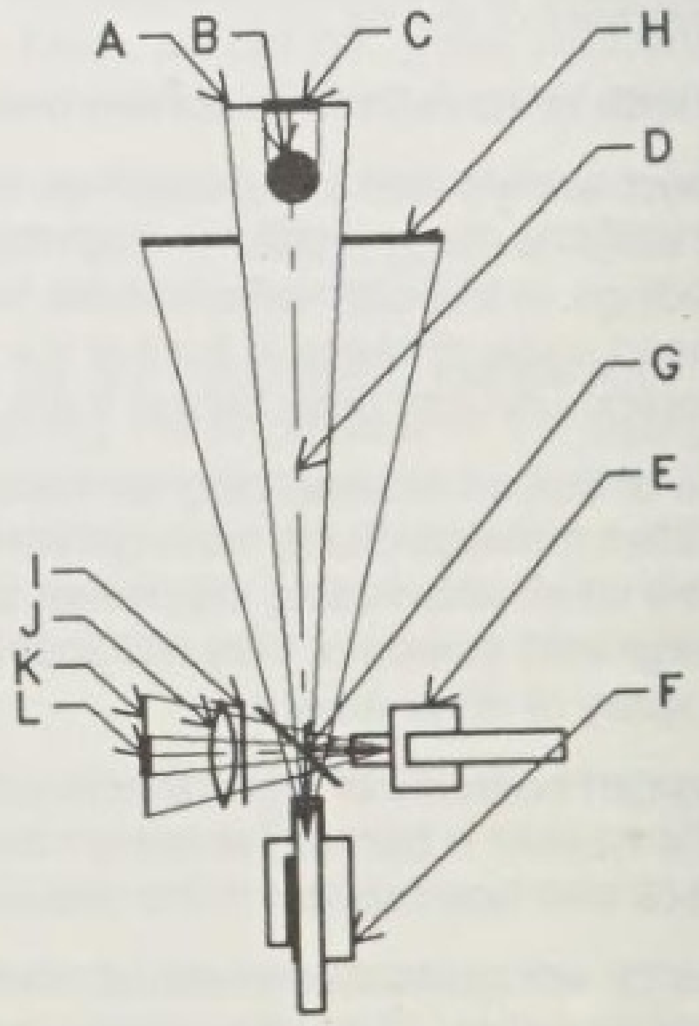


REVERSE FRONT PROJECTION: A. Scotchlite screen; D. Optical axis; E. Projector; F. Camera; G. Large semi-reflecting mirror; H. Black light absorbing screen; I. Foreground subject in front of the semi-reflecting mirror.

Twin screen systems

If the black baffle of the normal FP configuration is replaced by a second retro-reflective screen the camera will see two screens simultaneously and by placing a diopter lens between the projector and the second screen it is possible for the second screen to be very much smaller than the main screen, thus economizing on the size of screen required. Complementary mattes and a neutral density filter to control the brightness of the small screen complete the system. A typical example of the use of this system is to photograph a foreground subject in front of an archway, with a lot of movement going on behind, while the rest of the building is photographed off the small screen.

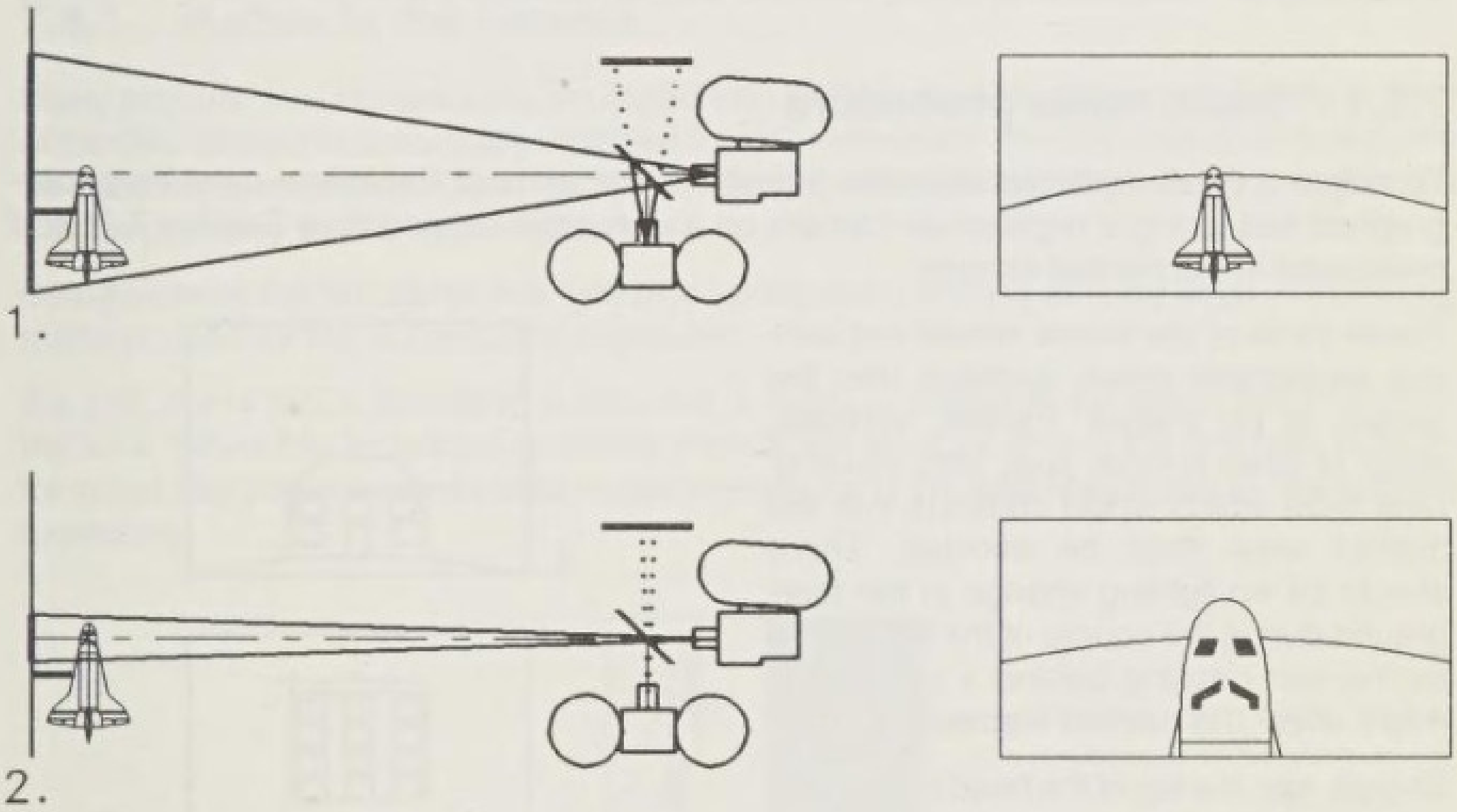
Introvision Inc. use two screens, combined with large mattes, to place an artist 'within' a background plate. A large sheet of plate glass is placed between the artist and the camera and any item or part of the background plate that the artist is to pass behind is blacked out on the plate glass surface. A complementary matte of retro-reflective material is arranged on the other side of the beamsplitter, leaving the rest black.



TWIN SCREEN SYSTEM: A. Scotchlite screen; B. Foreground object; C. Foreground shadow; D. Optical axis; E. Projector; F. Camera; G. Semi-reflecting mirror; H. Black matte complementary to L; I. Light attenuating filter; J. Diopter lens; K. Small Scotchlite screen; L. Black matte complementary to H.

Twin zoom lenses

Another proprietary FP system is the Zoptic system, developed by Zoran Perisic. This system uses zoom lenses on both the projector and the camera, 'zooming' them in sync. The system gives a good impression of a foreground subject flying towards or away from the camera while at the same time the size of the background image remains constant. It was used extensively on the early SUPERMAN pictures and was contributory to creating the illusion that a man really could fly.



THE ZOPTIC TWIN ZOOM LENS SYSTEM: 1. Photography and projection by wide angle of zoom lens making the model look distant; 2. Photography and projection by long focus end of a zoom lens making the model appear to be close to the camera. (Model turned 90° in illustration for convenience)

Two projectors

A second projector (usually a simple slide projector) can be introduced into the optical path, and be correctly aligned, by the use of a second beamsplitter mirror between the projector and the main beamsplitter. This is useful if a second projected image is required. Either the two images must occupy a different part of the screen, separated by a foreground object, or mattes can be used to ensure the two images do not overlap.

Using the back of the mirror

Atmospheric effects (rain, snow, etc.) can be deployed between the back of the beamsplitter mirror and the black baffle, and lit separately, to give the illusion that they are falling in the scene.

Variable speeds

Background plates can be shot out of speed (faster or slower), and combined with live action in the foreground at normal speed. This is particularly useful when combining miniatures with real people.

Alternatively, a plate can be shot out of speed and the projector/camera run at the same speed so that the foreground action appears to be speeded up or slowed down when eventually projected at 24 fps.

7.5 GLASS MATTE AND BIPACK CINEMATOGRAPHY

Many creative films depend to a great extent on painted matte shots to portray places, buildings, parts of buildings and objects which are not practical to construct. Such scenes consist of areas of live action combined with painted or still photographed scenes.

Low buildings with busy street foreground action may have extra storeys added to make them skyscrapers. Distant mountains may be added to a desert foreground, unwanted areas may be obliterated by being overlaid, and so on. There are few limits.

7.5.1 Glass matte procedure

To create a glass matte combination scene the live parts of the scene must be photographed first, using a register-pin camera on a very solid support (see Section 7.8) and processed in the normal manner.

These parts of the scene should not contain movement which overlaps into the portion to be matted. People, vehicles, water or even smoke, dust, rain, cloud or heat haze which would continue into the matted area must be avoided. There should be no lighting change in the foreground during the course of the take, such as the sun passing behind a cloud, that might affect the painted element.

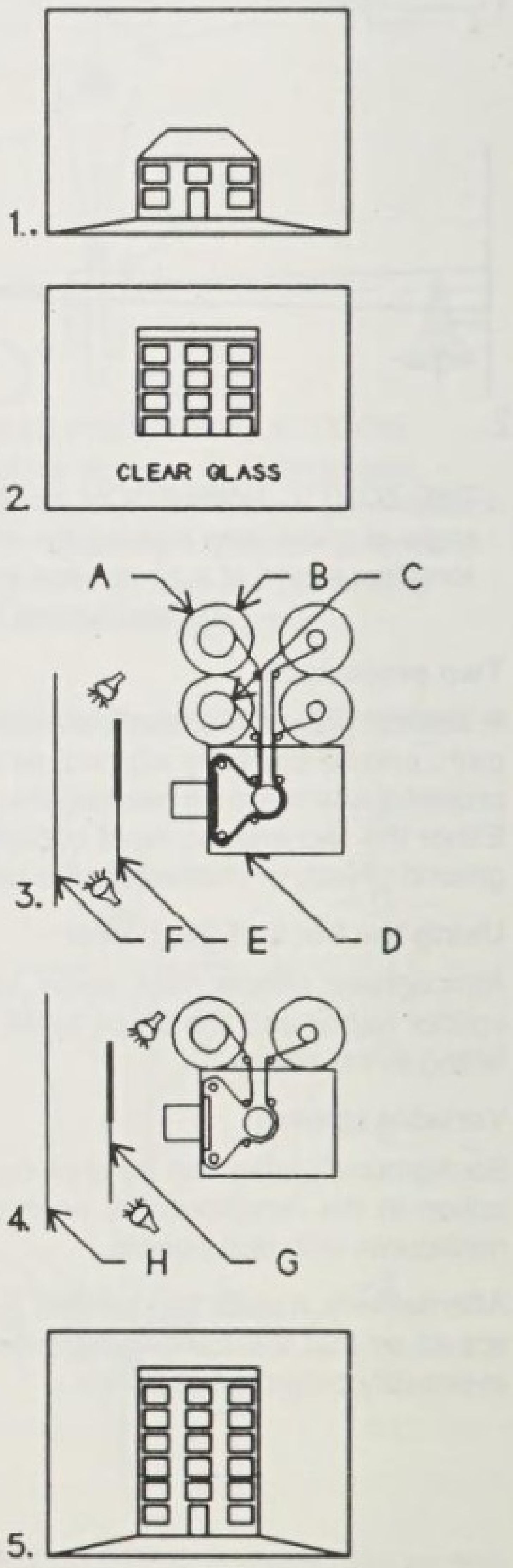
Should, say, the top of the head of a person in the live action foreground, break through the matte line the problem can only be corrected subsequently by a time consuming and expensive frame by frame rotoscoping exercise.

A well-timed (color-graded) print is made of the original negative using a step-printer. This is called the 'master positive'.

A clip from the master positive is put into a register-pin projector, which may be a process camera from which the rear pressure plate has been removed and replaced by a prism and lamphouse (a Rotoscope). The selected frame is projected onto a large piece of glass on which the area to be matted is traced and the areas to be matted are painted on.

The 'master-positive' is laced into a bipack process camera in 'emulsion-to- emulsion' contact with unexposed duplicate negative stock. The glass matte is then photographed with no light on the painting but with a well-illuminated white card behind to form a printer light for the required part of the original scene. These are passed through the camera.

Alternatively, the original negative may be used to make three B&W RGB color separations to be used in bipack with another negative to re-create the original scene color and quality. An interpos of the original scene is made and used in bipack with an interneg. The film is rewound and rethreaded on its own. The painted area of the glass is now illuminated, the live action area blacked out and the dupe-negative passed through the camera a second time.



1. ORIGINAL PHOTOGRAPHY
2. AREA TO BE MATTED-IN IS PAINTED ON GLASS
3. BIPACK PHOTOGRAPHY STAGE 1:
A. Bipack magazine; B. Unexposed duplicating stock; C. Master positive; D. Camera; E. Unlit matte painting on glass; F. Illuminated white background.
4. BIPACK PHOTOGRAPHY STAGE 2:
G. Lit matte painting; H. Unlit black background
5. COMBINED IMAGE

7.6 DOUBLE EXPOSURE MATTES

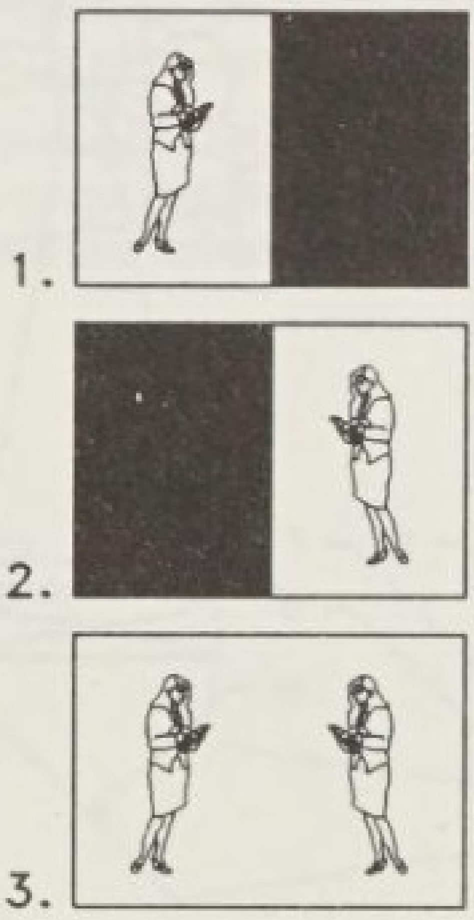
The combining of several live action scenes into one by the use of mattes is a process which can be carried out in the camera or in an optical printer. The advantage of doing it in the camera is that every part of the scene is a first-generation image with no loss of quality whereas in the optical printer the advantage is that every element can be separately manipulated for the best final effect.

7.6.1 Mattes in the camera

Many professional cameras are equipped with a slot in the film gate, immediately in front of the film. While this is normally intended for color correction filtering it can also be equally be used for hard mattes. Older cameras, Mitchell NCs and BNCs particularly, had such mattes provided as standard equipment.

Being close to the film plane, this type of masking has a sharply defined edge. A matching matte is used for the subsequent exposure.

If a soft, out of focus, transition is required, a matte is placed in the matte box in front of the lens. When this technique is used sufficient film must be shot of the first take to allow for some trial-and-error tests to be made in positioning the matching matte for the second exposure.



CAMERA MATTE CINEMATOGRAPHY: 1. Original scene is photographed with unwanted area masked off; 2. Original negative is passed through camera a second time with complementary part of the image masked off; 3. Result, a combined image on a single original negative.

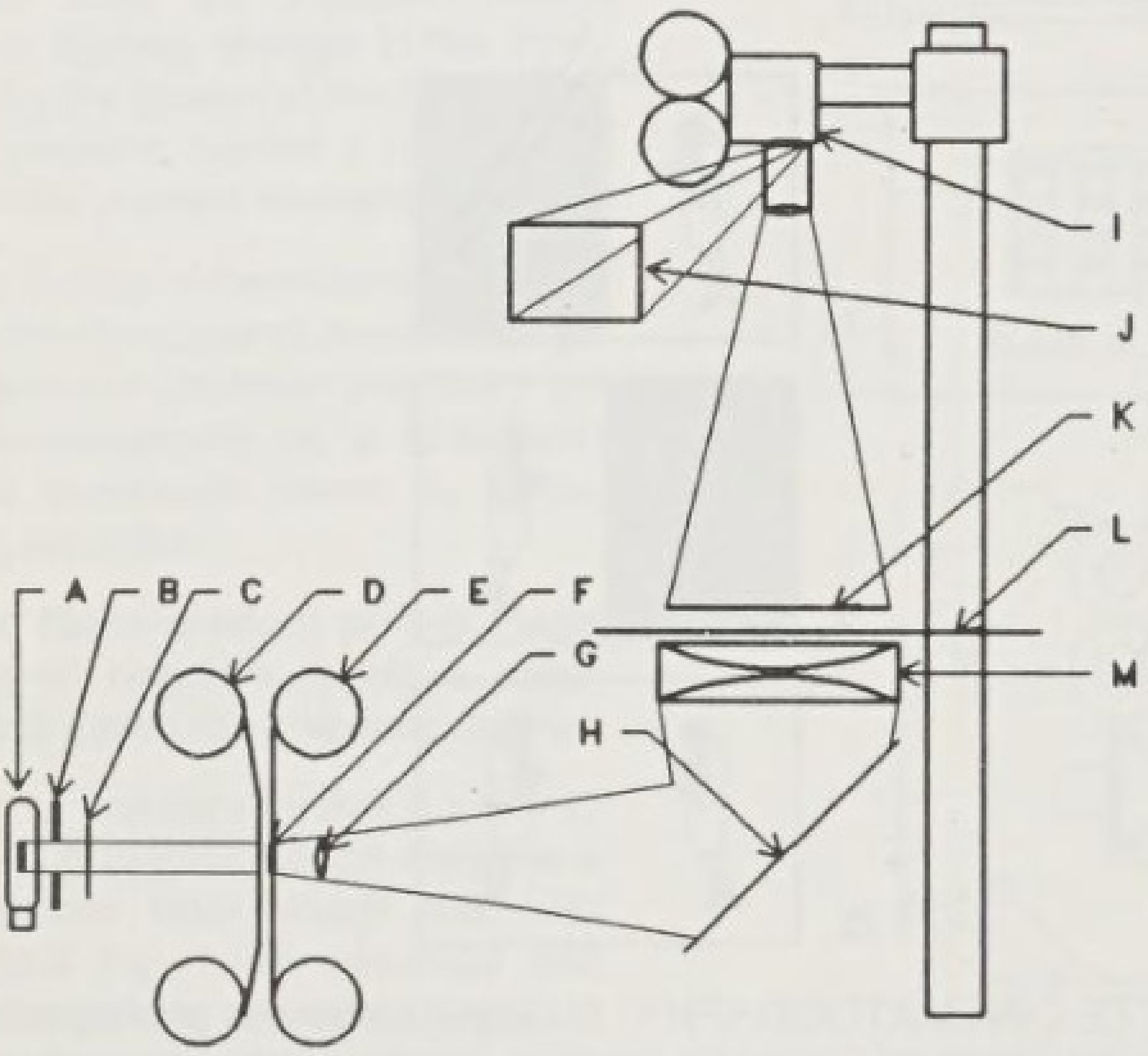
7.7 OPTICAL PRINTING AND AERIAL IMAGE CINEMATOGRAPHY

Optical printers are printers which handle the original film to be printed and the film onto which it is to be printed independently rather than in contact. Both elements are advanced frame by frame and held on fixed registration pins during the printing period. The image is transferred from the original to the copy by projection, allowing for a great deal of manipulation in the process.

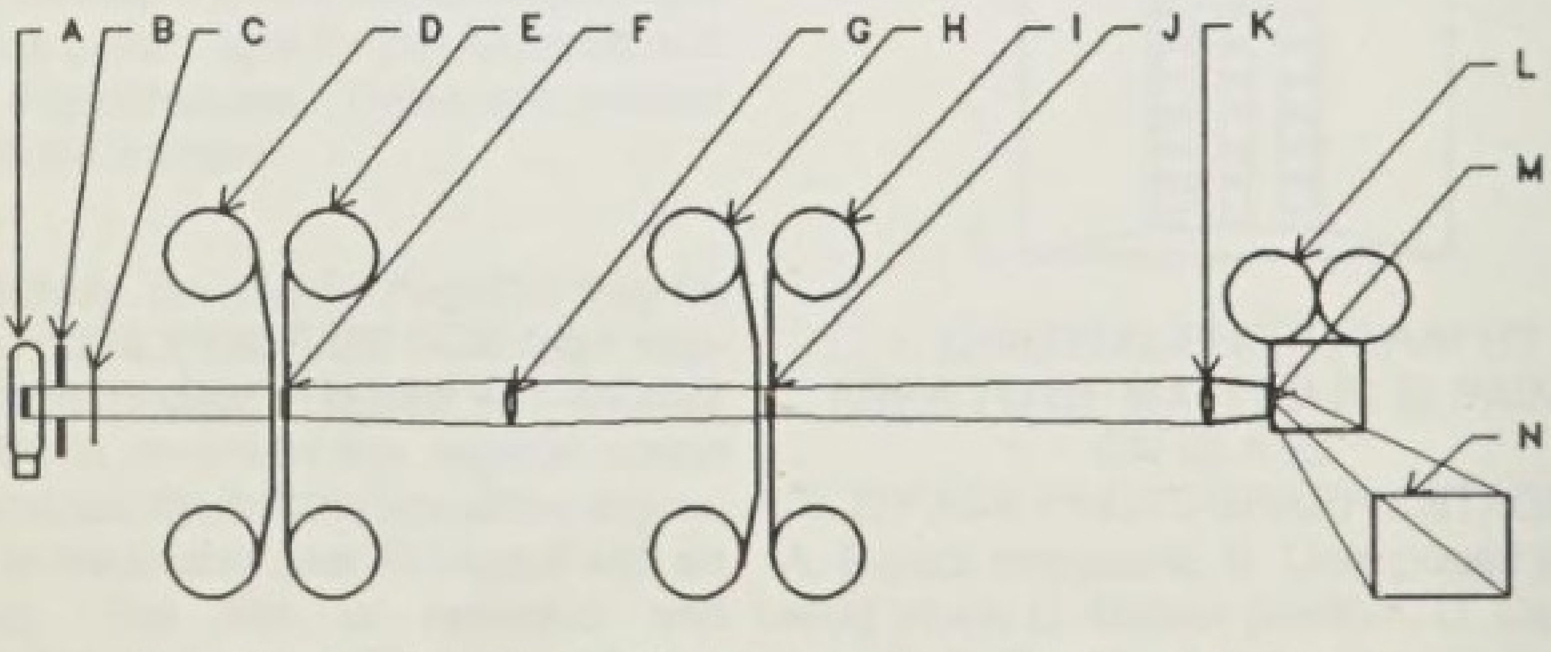
Put very simply, 'Aerial Image Optical Printing' is miniature back projection without the need for a translucent screen between the projector and the camera.

The great advantage of aerial image technology is that during the set-up period two (or more) film elements (with their mattes) which have to be composited can be viewed simultaneously and their sizes and positions adjusted relative to one another before printing commences.

Aerial image printers can either be vertical, in the form of an animation rostrum, or horizontal in the form of an optical printer.



SIMPLIFIED AERIAL IMAGE ANIMATION ROSTRUM LAYOUT
A. Underneath projector light source; B. Light attenuator; C. Filter pack; D. Film; E. Matte; F. Projector gate 1; G. Projector lens; H. Mirror; I. Camera; J. Reflex viewfinder; K. Platen; L. Table top; M. Condenser lens.



SIMPLIFIED AERIAL IMAGE OPTICAL PRINTER LAYOUT
A. Projector 1 light source; B. Light attenuator; C. Filter pack; D. Film 1; E. Matte 1; F. Projector gate 1; G. Lens focusing image onto gate of projector 2; H. Film 2; I. Matte 2; J. Gate of projector 2 and image formed from projector 1; K. Camera lens; L. Unexposed filmstock; M. Camera gate; N. Reflex viewfinder

7.7.1 The Aerial Image animation rostrum

Aerial Image animation rostrums are much used for the purpose creating mattes from live action film or to combine frame by frame animation with 24 fps live action footage shot with a normal camera.

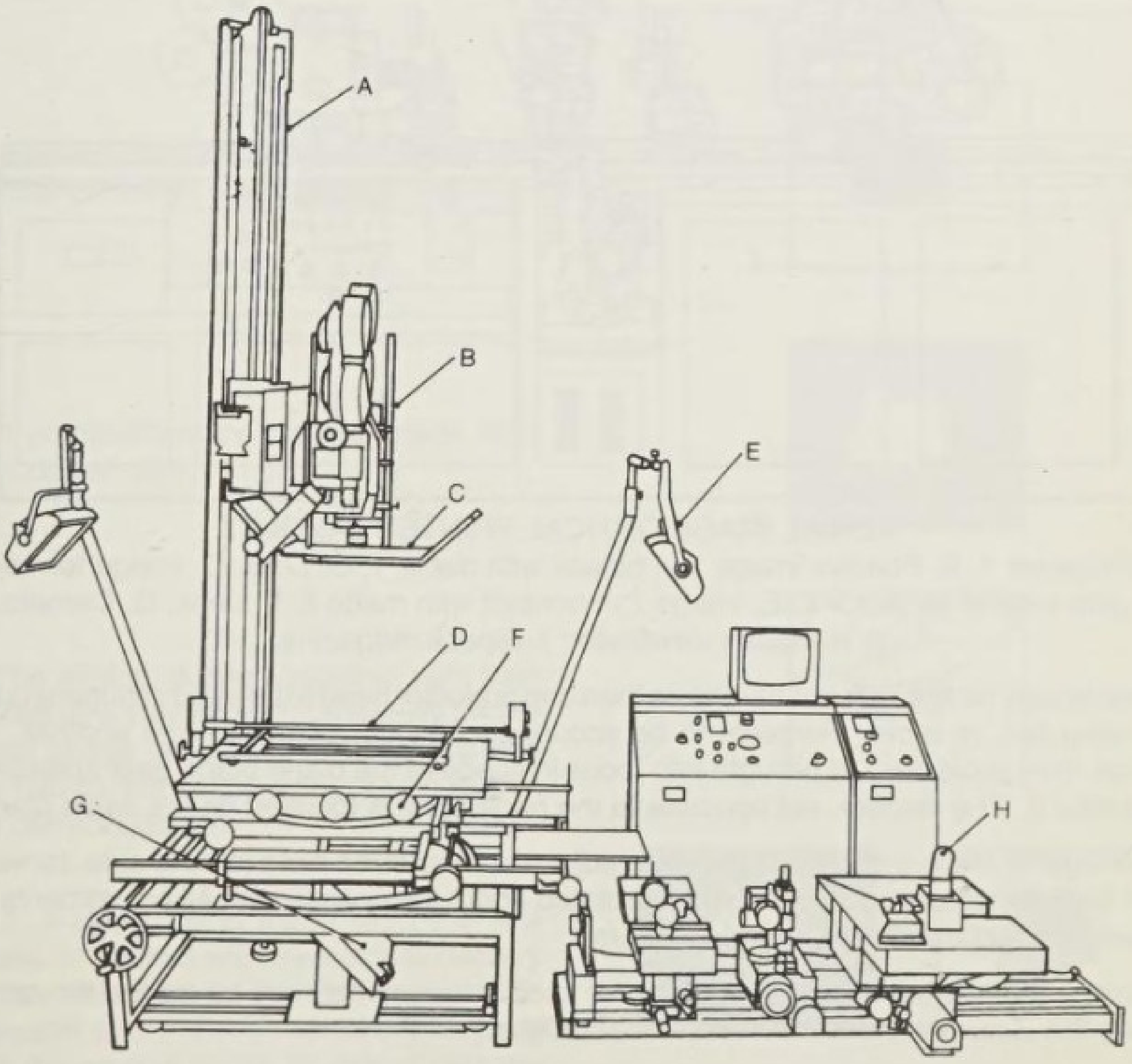
From the bench up the Aerial Image animation rostrum is much like any standard such rostrum. The camera support, on which the camera may be moved smoothly up and down, is a vertical column of immense rigidity. The camera is of the type specially designed for animation work, the bench is fitted with the standard animation cell registration pins and has E/W, N/S and rotational movement capability.

The big difference is that the bench is made of plate glass beneath which is a large condenser lens which focuses the aerial image from the projector onto the surface of the unexposed film.

Beneath the condenser lens is a mirror set at 45° and to the side of this an optical projector which can be run independently or in electronic synchronization with the camera. The projector can be run in bipack with a matte and in tandem with a second aerial image projector if required.

To create a matte the original film is projected frame by frame onto glass surface of the work table and the matte drawn and then photographed. Very often the required matte is just a 'garbage' matte to hide model and puppet supports and wires which are in front of a blue backing matte. If this is the case the matte need only be accurate at the edges. In other cases a full matte around a whole area of a live action image may be required.

When combining live action film animated film the animation cells are placed on the work surface and the live action image projected from beneath, the opaque backing of the cells acting as a matte hiding unwanted live action image areas.



ANIMATION ROSTRUM WITH TWO AERIAL IMAGE PROJECTORS
A. Camera support column; B. Camera; C. Shadow board; D. Animation table top with peg bar; E. Cell illumination; F. Controls enable work to be moved on any axis; G. Mirror; H. Aerial image projection unit.

7.7.2 Aerial Image optical printer

The work-horse of special effects, the optical step printer is used for a multitude of production tasks. Typical of the tasks that can be done on an optical step printer are the following:

1/1 printing where image steadiness is of paramount importance

Anamorphic/spherical conversion

Bipack printing

Blow-ups and reductions between 65, 35 and 16mm film sizes

Burn-in titles

Diffusion and out of focus effects

Dissolves and fades, 4 to 999 frames

Double exposures

Drop shadows

Flip over

Flips and spins

Forward and reverse action

Frame line correction

Freeze frame

Image tilt and tilt correction

Multi-exposure

Push-offs

Reduction and enlargements

Scene to scene color correction

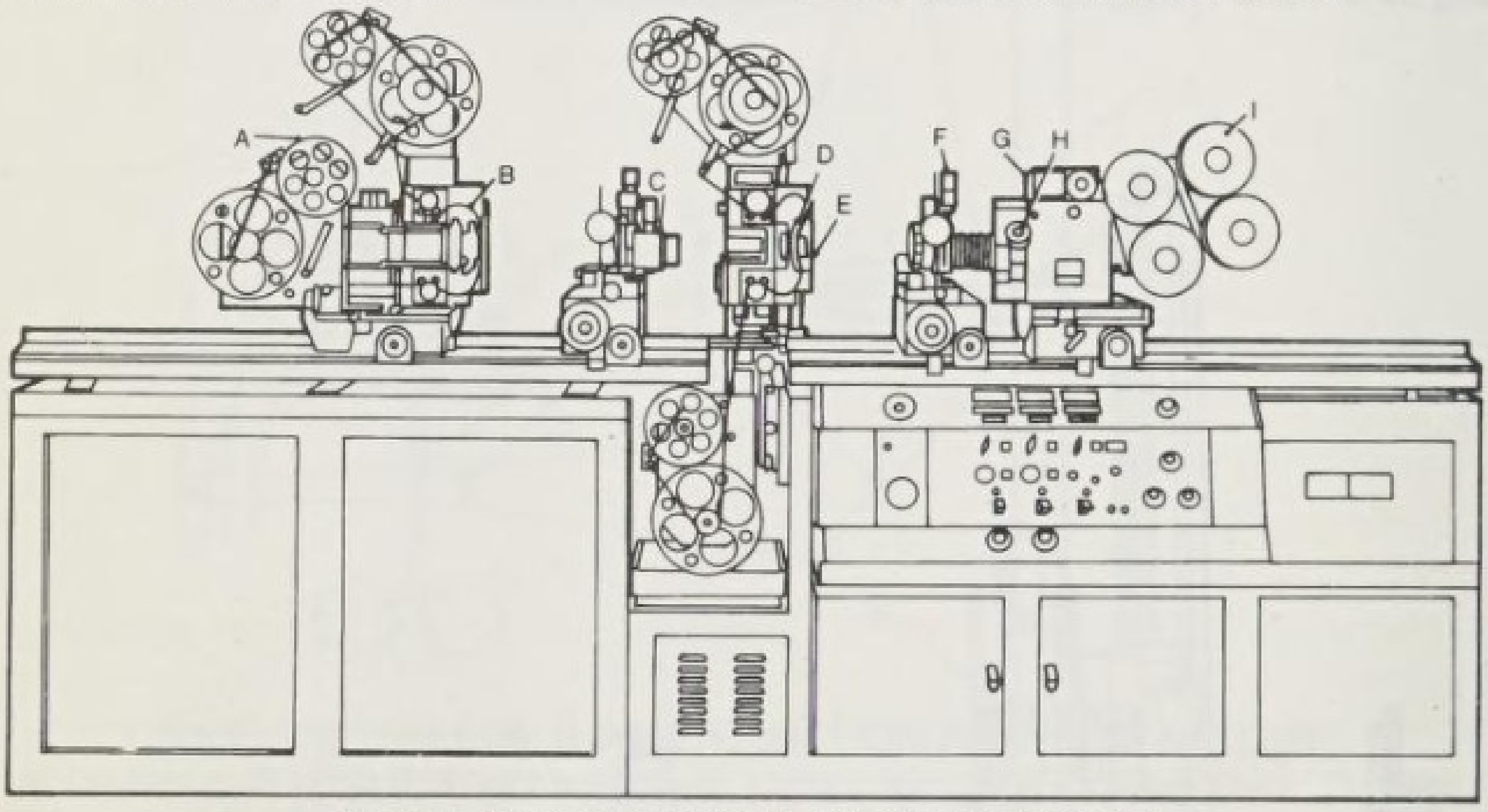
Skip frame

Split frame

Titles

Travelling matte

Zooms, straight and off center



AERIAL IMAGE OPTICAL PRINTER LAYOUT.
A. Projector 1; B. Positive image 1 in bipack with matte 1; C. Lens; D. Image formed in gate area of projector 2; E. Image 2 in contact with matte 2; F. Lens; G. Camera; H. Reflex viewfinder; I. Bipack magazine.

Aerial Image technology enables more than one projector head to be used simultaneously, allowing two, or more, elements to be accurately aligned relative to one another. The image from projector 1 is brought into focus in space at the plane of the gate aperture of projector 2. The camera, set opposite to the projectors, is focused on the same plane.

All elements of the system can be micro adjusted on all three axes (side to side, forwards and backwards and up and down) and rotated about the optical axis. All adjustments are measured and monitored by micrometers.

Focus is maintained automatically so that zoom movements may be made (movement along the *Z* axis) without the need to manually adjust the lens.

Exposure is controlled by a light valve which affects neither the color of the light or the optical characteristics of the lenses. Color correction and other filters may be placed in the light path to match and balance the color and the look of both images.

The optical printer illustrated has a single light source used by both projectors. When this type of equipment is used each element is run separately so that each may have its own light correction. More elaborate optical printers have the central projector, with its own light source, set to one side and the images combine by a beamsplitter in the optical path.

7.7.3 Mattes in the optical printer

As with glass mattes (Section 7.5) the live action elements of the scene are first exposed in the normal manner, positioning the camera on each occasion so that the images are correctly placed in the frame area (see Section 7.8)

A frame from the background scene is projected onto a white card using a process camera fitted with a rotoscope attachment (a simple lamphouse which turns a camera into a projector for the purpose of matte drawing). A line is drawn where the images are to be joined and one side is painted matt black.

This is then photographed, either in-focus, if a clear-cut join is required (to line up with the edge of a building, etc.), or out-of-focus if a soft join is more desirable,

From this negative matching mattes are made on high contrast B&W stock using a step contact printer.

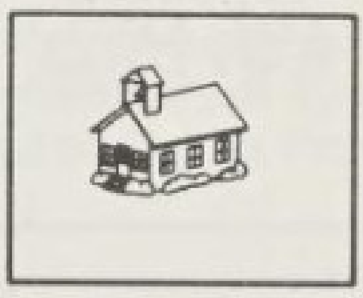
Composite second generation negatives may be made from the original negative (printed in contact with the related matte), onto a CRI internegative or from intermediate positives of the original negatives.

As already mentioned (Section 7.5.1), if the parts of the scene to be matted in contain movements which butt into the joining line, a whole series of frame-by-frame mattes may have to be drawn and photographed on an animation table.

A second (auxiliary) matte may be made from the background scene allowing a moving object which may have been photographed by a travelling matte, to be inserted 'into' a scene. Thus, a person could be seen to move behind an object which originally formed part of the background.

1, 2. Original scenes are photographed as plates. Stock shots may be used provided they conform to the necessary image steadiness standards.

1.



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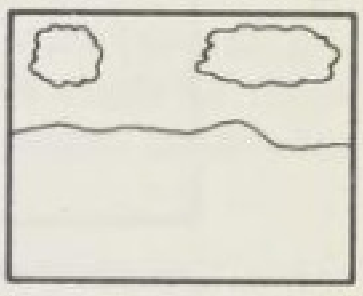
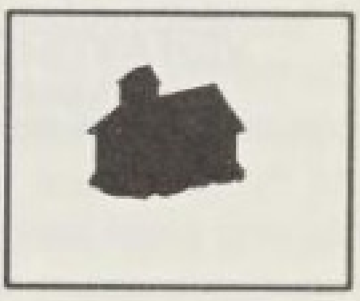


3. A close fitting black matte is drawn and photographed on high contrast filmstock.

3.

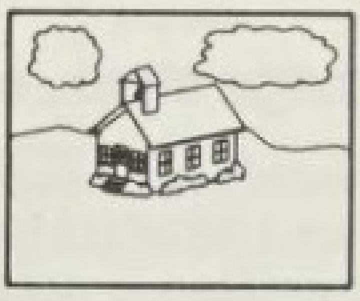


4. A complementary matte is made from the original matte.

4.

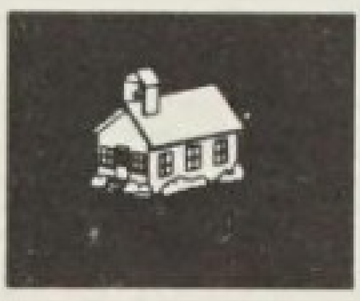
5. The original scenes, together with their mattes, are viewed simultaneously on the aerial image optical printer to check that the mattes are of the correct size and in the correct position.

5.

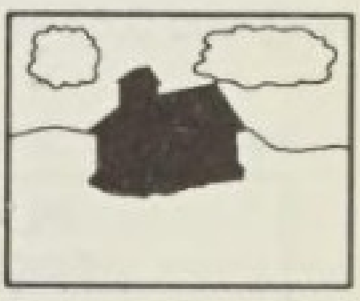


6, 7. A duplicate is made from the first scene, in contact with the complementary matte. The film in the camera is then rewound and the second film, in contact with the original matte, is printed onto the unexposed portion of the negative.

6.

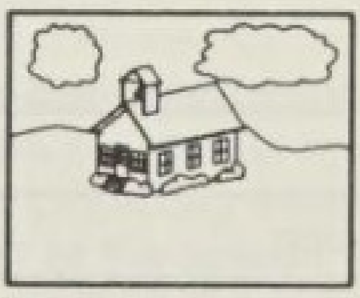


7.



8. The result is a combined duplicate negative with individually corrected color and exposure for each original element.

8.



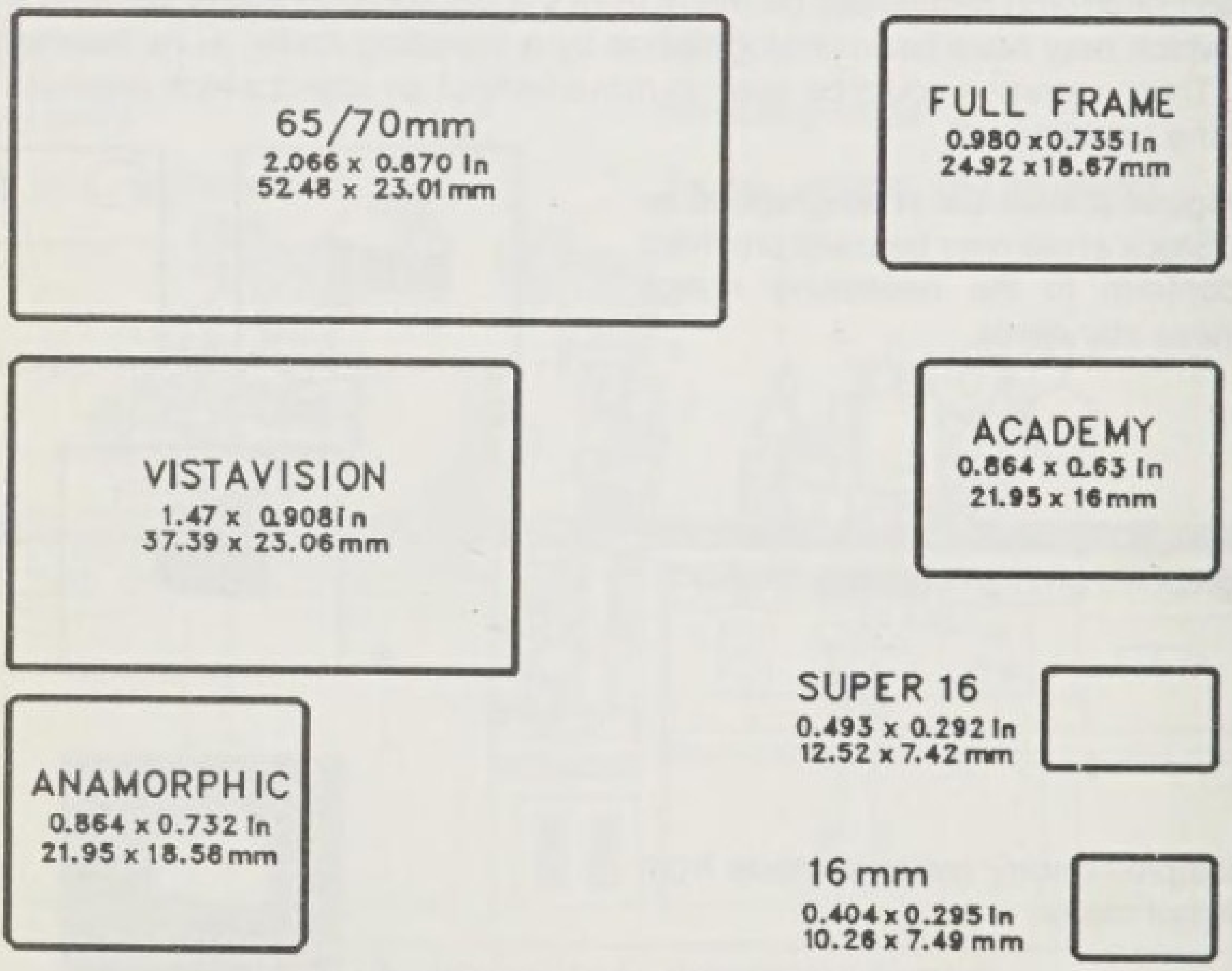
7.8 SHOOTING BACKGROUND PROCESS PLATES

Optical quality, image steadiness, fineness of grain and suitability in terms of foreground image matching of perspective, scaling, direction, inclination (tilt), level (cant), height, speed, lighting direction, color balance and contrast, etc. are the ingredients of a good process plate and a prerequisite for successful process cinematography. Close cooperation between the camera person shooting the plates and the Art Director, the Film Director, the Laboratory, the Production Director of Photography, the Special Effects Coordinator, the Special Effects camera person and the technician who is responsible for marrying the various elements together is a vital necessity.

7.8.1 Image quality

To a large extent the quality of the plate image will depend upon the size of the film format used (the larger the better) and this in turn will depend upon the equipment available to handle it. Depending upon whether the optical house or the projector, in the case of Front or Rear Projection, is geared to 65mm or Vistavision or regular 35mm so will be the choice of camera format for shooting the plates be dictated.

If the plate is only to be used to insert an image over a part of the full format, or if, as may happen with Front or Rear Projection, it is only being used to place a background image in a background window area, then the question of copy ratio is less critical.



COMPARATIVE CAMERA IMAGE SIZES

7.8.2 Image sizes, copy ratios and usable plate area

While the respective camera image areas of 65mm, Vistavision and 35mm Full Frame (Super 35) are 1.88 in^2 (1210 mm^2), 1.472 in^2 (949.5 mm^2) and 0.720 in^2 (465 mm^2) which is most advantageous depends upon whether the production is being shot with an Academy or Anamorphic aspect ratio, the camera image areas of which are 0.54 in^2 (351 mm^2) and 0.63 in^2 (407 mm^2) respectively.

Usable plate area

PLATE FORMAT	PLATE IMAGE AREA (in^2)	PRODUCTION FORMAT USABLE PLATE IMAGE AREA	
		Academy (in^2)	Anamorphic (in^2)
65mm	1.66	1.05	1.38
Vistavision	1.47	1.36	0.94
35mm Full Frame	0.65	0.63	0.37

From the table it will be seen that there is a greater copy ratio possible by using a Vistavision plate with an Academy production format and of using 65mm with an Anamorphic format. (See also Section 7.4.3.)

If a 35mm Full Frame plate is to be shot it is important that the camera lens be re-centered as for Super 35. This is important to even-out any fall-off of image brightness in the corners of the picture and to make it possible to 'flop over' the plate so that it may be used in either direction.

7.8.3 Choice of filmstock

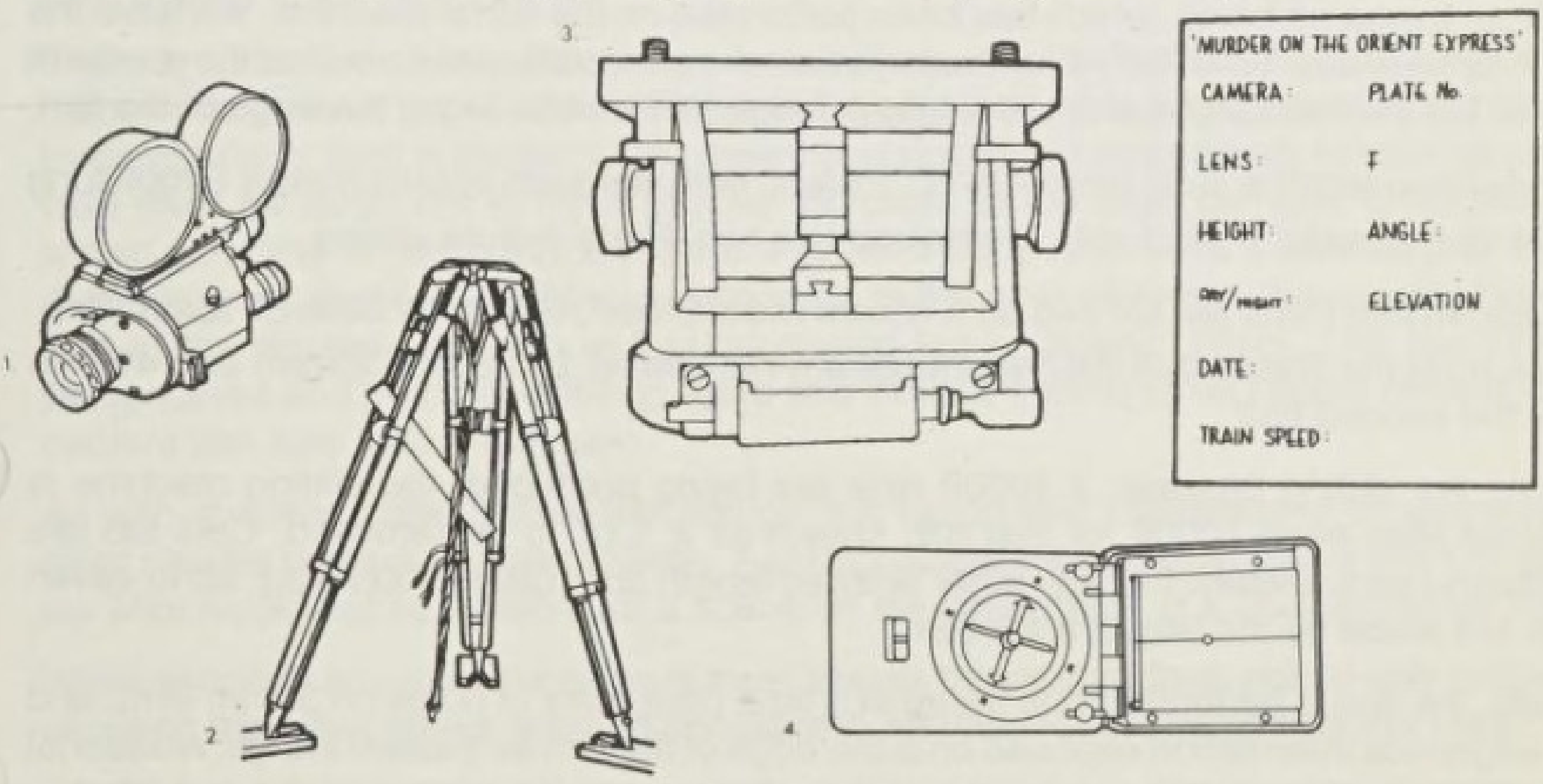
Prudent choice of filmstock for both the plates and the production can improve the quality ratio every bit as much as image size. With the modern generation of filmstocks there is now very little to choose in terms of image quality between the faster and the slower filmstocks. Best to choose the slowest speed filmstock which permits a full exposure at a middle of the range aperture to ensure optimum optical and photographic quality.

7.8.4 Image steadiness

When the final combination of foreground and background images is to be done optically (i.e. in a camera or a step-printer) and when there are static objects in both the foreground and background elements of the shot there can be no half measures when it comes to ensuring image steadiness in the process plate. When the final compositing is to be done with computer generated images then the film element needs to be steadier still, if that is possible!

When shooting plates the camera must be supported on a substantial tripod or top hat, and on a heavy duty head. A dolly with rubber wheels is not steady enough for plate shooting unless it is raised off the ground and supported on three wooden blocks for maximum rigidity.

The pan and tilt head must be locked off securely and, if necessary, screw jacks put under both the front and back to solidify the tilt. The boat or quadrant of a geared head may need clamping to its side supports. Wedges may need to be pushed between the camera and the tripod head. If there is wind a wind break may need to be constructed and, in extreme cases, sandbags may have to be built up from the ground and wrapped around the camera head to solidify the support. Other useful items are tie-down chains, turnbuckles, sash cord, 'G' clamps, weights, crow's feet, large screw eyes and stage hooks.



EQUIPMENT FOR SHOOTING PLATES:
1. Register pin camera; 2. Sturdy tripod; 3. Rugged head with locks; 4. Combined compass and clinometer; 5. Detailed marker board.

Should it be absolutely necessary to shoot a plate from a scaffold tower there should be a plentiful number of stays and cross braces and, where possible, the camera support should be attached to the tubing rather than to any flooring.

If a process plate from a stockshot library is to be used for a static background it should first be checked for steadiness. This can be done by double printing it in an optical printer together with a grid pattern and then projecting the result, or projecting it with a register pin projector and comparing it to a static object set in front of the screen. Stock-shot libraries are an invaluable source of ready made plates but not all the most attractive scenes were shot with process cinematography in mind and care must be taken if a rock steady background element is essential.

To check that the camera is not moving, or even vibrating, while it is running, place a small dish of water on the camera body or magazine. By observing the reflection of a lamp or the sun on the surface any vibration will be seen quite clearly as a ripple. An even more sensitive test is to observe a reflection from the sun or a lamp off the water on a fixed surface, such as a wall or the ceiling. By this method even the slightest movement will be magnified and easily seen.

The camera to be used should be checked before use by shooting a double exposure test at the fastest speed likely to be used, and if reverse running is contemplated, in reverse also. For such double exposures an all-over grid pattern should be photographed, displacing it slightly in a diagonal direction between runs. (See Section 5.5.)

When looking at a double exposure test on projection it is particularly important to take special notice of the relative position of the pairs of lines at the top and bottom of the frame. If there is any unsteadiness due to film movement before the shutter is completely closed, or if the shutter has begun to open while the film is still moving, it will appear as movement at the top and bottom of the frame, depending upon which way the shutter revolves relative to the frame.

Cinema projectors are normally fitted with Maltese cross type movements. To get more light on the screen with these movements the film is still moving after the shutter has begun to open and is moving again before the shutter closes. For this reason such projectors cannot be used for assessing image steadiness unless a double exposure type test has been made.

7.8.5 Selecting filmstock

In the final analysis image steadiness depends not only on the performance of the camera but also upon how accurately the filmstock has been perforated and its dimensional stability. Filmstock manufacturers go to great lengths to produce film which is within the tolerances laid down by the various National and International Standards bodies but all perforating punches and dies wear as they are used and should it so happen that a punch and die is at the end of its useful life when a particular roll of film is perforated, while still being within the tolerances laid down, the resulting perforations may be too loose for the most critical multi-exposure process cinematography techniques. Where image steadiness is that critical tests should be done beforehand and a note taken of the batch identification information of each roll of film.

Once a satisfactory roll of film has been identified it can be safely assumed that any other roll from the same batch, which has been perforated on the same machine, will have the same dimensions. To identify a particular filmstock note must be taken both of the numbers printed on the film can label and the latent image information along the edge of the film.

An emulsion batch is sufficient for 5–50 ‘Parent’ film rolls each approximately 6000ft long by 54 inches wide. Parent rolls are halved into two ‘Parts’ before slitting.

For 35mm film Parts are slit into 38 × 35mm wide ‘Strips’, (83 in the case of 16mm film). Strips from the first half of the Parent roll are numbered 1 - 38 (for 35mm) and 41 - 78 from the second half.

During the slitting process, if 1000ft rolls are being produced, the slitting machine is stopped after each 1000ft for that roll, known as a ‘Cut’ to be removed. Cuts too are numbered sequentially. For any other finished length but 1000ft (400ft etc.), up to seven Cuts are made by the use of a spooler.

Finally, the film is perforated one frame at a time (four pairs of holes on 35mm film). and the edgecode information exposed onto the edge of the film as a latent image. Additional information relating to the emulsion and the roll, etc. may be printed on the can label.

7.8.6 Keeping selected filmstock in good condition

The dimensional stability of the film depends not only upon the accuracy with which it is manufactured in the first place but also how it is stored and handled subsequently. When film is packed immediately after perforating and put into a black bag, a vacuum tube is inserted into the package before the final fold is made to exhaust as much air as possible. It is then placed in a can in an environment which is stabilized at the optimum humidity for good storage conditions, and sealed with tape. So long as the film remains sealed in that environment and is kept within reasonably cool temperature conditions it will remain dimensionally stable.

Once the can is opened it is liable to shrink if exposed to too much heat for too long a period. For this reason filmstock which is intended for multi-exposure cinematography should not be loaded into magazines until required for use and should be processed as soon afterwards as is practicable, or kept in a correctly controlled environment. Re-cans should not be used.

7.8.7 Plate shooting techniques

For a combined picture to look believable there must be a unity between every element. While much composite work merely calls for a general view background which sets the scene somewhere, more specialized work calls for a matching of perspective and vanishing points as required by the art department. Where a background plate incorporates a part of a building which has already been designed, and even constructed, and the two must be blended together, the Art Director may well stipulate what focal length lens is to be used as well as the height, direction and inclination of the camera.

This is particularly important when a perspective set is to be built in the studio which may only be a few feet deep but looks to be very much deeper.

When a plate has been shot, especially if it is for a particular scene or setting, a data sheet must be completed which will give all the relevant information. It is also useful to place a stand-in in the foreground for a brief shot before shooting the plate, as a guide when setting up the composite scene.

Typical of the problems that may be encountered by using a plate which was shot without its use for a particular set-up clearly defined beforehand are that the camera may have been set at too high or too low an elevation, so that an artist cannot be set in the foreground without looking unnatural. If the plate camera is too high, for instance, only the head of a foreground person, set at the bottom of the frame, could be included in the combined scene because if he or she were placed full length it would look as though the person was standing on air. Similarly, plates shot with the camera set too low may only be suitable for including a foreground person up to knee height without looking unnatural.

A knowledge of the elevation and inclination of the plate camera makes it a simple matter to set the foreground camera similarly so that any person placed in the foreground will look to be standing vertically to the background.

Another problem that can occur, particularly if a wide angle lens was used on the plate camera, is that of a background person moving towards the camera and becoming larger than people in the foreground.

There are, however, many situations where it is important for a cinematographer to impart 'depth' into a plate, especially by the use of moderately wide angle lenses (long lenses, by comparison, tend to flatten out the scene and slow down movement). In such situations care must be taken not to have anyone too close to the plate camera. Other ways to impart a feeling of depth into a plate are to set the focus forward a little so that the far distance goes slightly out of focus compared to the near distance, the use of smoke or mist in the distance and the use of graduated fog or 'scenic' filters. The use of false perspectives and props of differing sizes and even of setting small people closest to the camera can also help the illusion.

As with shooting static plates of buildings, the height and inclination of travelling shots must also be given due consideration. A plate suitable for the background to a low sports car shot would not be suitable for a scene on the upper deck of a double-decker bus.

When shooting any plate the camera must always be set level from side to side and when shooting travelling plates account should also be taken of the camber of the road.

When shooting plates for backgrounds for motor bikes at racing speeds, thought must be given as to whether it is desirable for the background horizon to remain level or to tilt as would be the case when rounding a corner at speed. It may be necessary to use a second tilt head, set cross-wise to the first, to keep the camera at the desired level.

When shooting travelling plates it often looks better to slow down the plate vehicle when shooting sideways-on and 3/4-on plates, compared to head-on. Generally speaking, the plate vehicle should travel about 40% slower for sideways plates and about 20% slower for 3/4 back or forward plates. As the closeness of the background and the focal length of the plate camera lens also have some effect it is often wise to shoot the plates several times, with the vehicle travelling at various speeds.

If it is planned to project reflected images onto a travelling foreground subject it will be necessary to set a second camera to shoot in the appropriate direction to the plate camera. Both cameras should run at the same time and at the same speed so that as the background slows down, speeds up or stops, so too will the reflections.

As a general rule it is wise to avoid backgrounds which contain signs, hoardings or lettering of any kind which would look wrong if the plate needs to be 'flopped-over' later.

At the time of shooting plates it is a wise precaution to shoot still photographs from exactly the same position and angle as a record and guide for the Art Director, Construction crews, Prop buyers, the Director, the Director of Photography and the SFX Supervisor, and others, to refer to later. In certain circumstances it may also be advantageous to shoot stills on a large format camera so it may be used as an alternative to a cine plate for projection purposes.

7.8.8 Plate processing requirements

In order to ensure that the image steadiness and optical quality produced by the camera is reproduced in the print, the processing must be done with particular care and attention. The camera exposure should be full, to minimize grain size and to give a negative with good shadow detail, and be consistent between various set-ups to give continuity when a number of scenes are cut together.

Forced development, to give extra film speed, should not be resorted to as it causes increased grain size, but negative flashing, either in the camera or at the laboratory to gain increased exposure and shadow detail or to lower the contrast, is often quite useful.

If the plates are to be used for Front or Rear Projection the color bias and the density of the prints should be made to suit the projection system. If the screen is very large it may be useful to have the prints made lighter than normal and if the projection is biased to any particular color, to have them printed with a bias to the opposite color.

The film transport mechanisms of registration type process projectors and of optical printers usually require prints made with 'Negative' or 'B & H' type holes with a pitch of 0.1866" (4.740mm) perforations.

7.8.9 Still or stereo plates

An alternative to the motion picture plate is the still 'stereo' or 'transparency'.

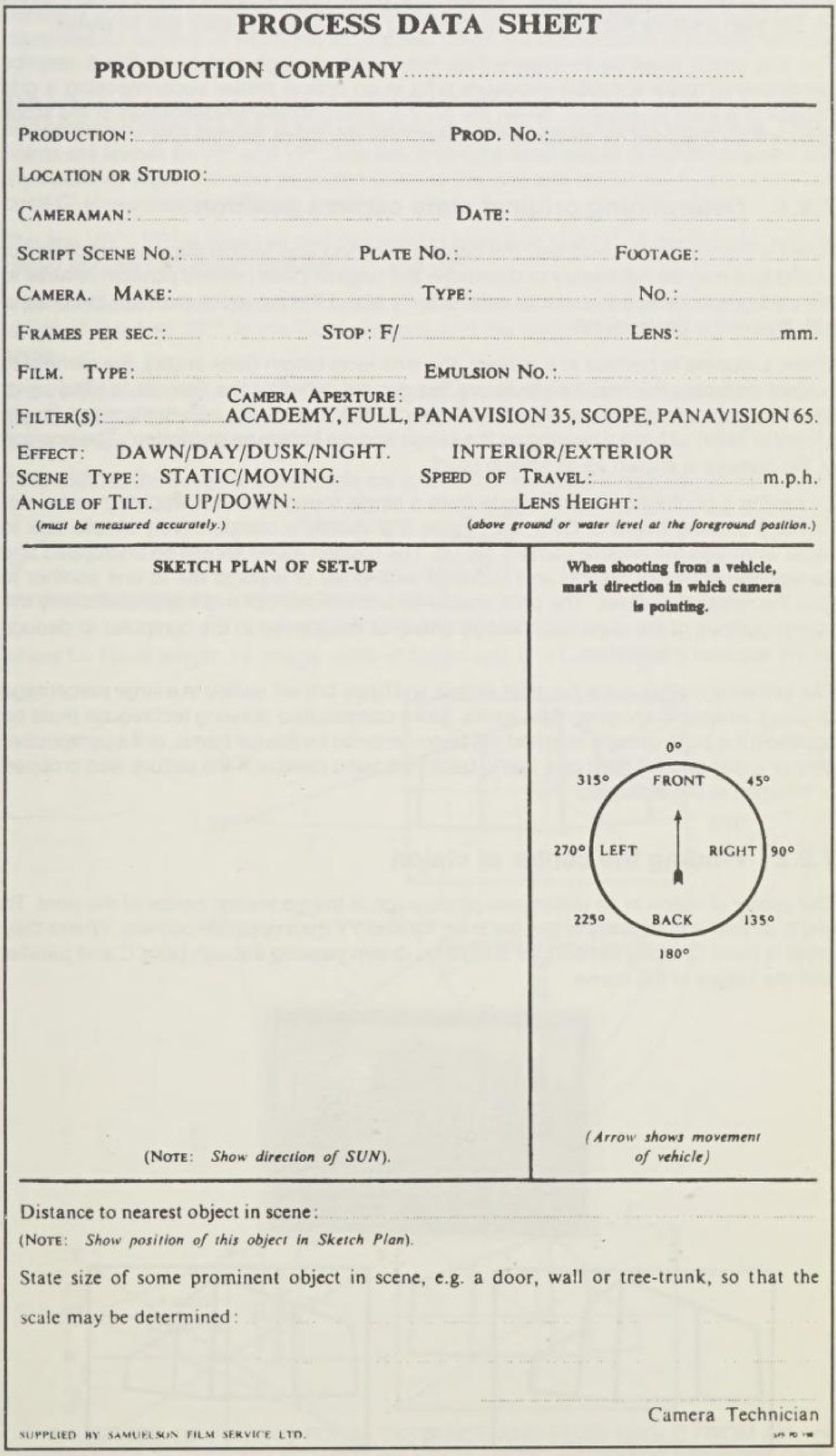
The rules regarding grain size and image enlargement ratio are even more severe in the case of a still background than they are with a motion picture image because in the latter case the superimposition of different grain patterns one after the other minimizes the appearance of grain. On the other hand, finer grain emulsions are sometimes available for still photography and formats of 5 × 4", and larger, are possible and frequently used.

'Still' stereos are not suitable for those subjects where an audience would expect to see movement, such as a busy street scene or water, but in some circumstances movement may be imparted to a 'still' background by motorizing the transparency holder to make it move up and down or side to side or rotate.

7.8.10 Plate shot log

It is most important to keep an accurate record of every plate, as it is shot, for the benifit of those who have to match foreground action at a later date.

Copies of the log should be placed in the can with the original negative so that is always available, even if the shot later becomes a part of a stockshot library.



PROCESS DATA SHEET

PRODUCTION COMPANY...

PRODUCTION: .... PROD. NO.: ....

LOCATION OR STUDIO: ....

CAMERAMAN: .... DATE: ....

SCRIPT SCENE NO.: .... PLATE NO.: .... FOOTAGE: ....

CAMERA. MAKE: .... TYPE: .... NO.: ....

FRAMES PER SEC.: .... STOP: F/ .... LENS: ....mm.

FILM. TYPE: .... EMULSION NO.: ....

FILTER(S): .... CAMERA APERTURE: ACADEMY, FULL, PANAVISION 35, SCOPE, PANAVISION 65.

EFFECT: DAWN/DAY/DUSK/NIGHT. INTERIOR/EXTERIOR

SCENE TYPE: STATIC/MOVING. SPEED OF TRAVEL: ....m.p.h.

ANGLE OF TILT. UP/DOWN: .... LENS HEIGHT: ....

(must be measured accurately.) *(above ground or water level at the foreground position.)*

SKETCH PLAN OF SET-UP

(NOTE: *Show direction of SUN*).

When shooting from a vehicle, mark direction in which camera is pointing.

(Arrow shows movement of vehicle)

Distance to nearest object in scene: ....

(NOTE: *Show position of this object in Sketch Plan*).

State size of some prominent object in scene, e.g. a door, wall or tree-trunk, so that the scale may be determined: ....

....

Camera Technician

SUPPLIED BY SAMUELSON FILM SERVICE LTD.

TYPICAL PLATE DATA SHEET

7.9 USING STOCK BACKGROUND PLATES

To save costs, and for convenience, it is often necessary to use background plates supplied by a stockshot library. If suitable shots exist, and if they were shot as plates, and all the documentation exists, then well and good. But if they are only suitable images on film then it will be necessary to check if they are also suitable for use as plates.

The first check must be to ensure they are steady enough and to do this it may be necessary to make a double exposure print in an optical printer superimposing a grid pattern of known steadiness. When the print is projected any unsteadiness in the stock plate will be apparent as movement between the stockshot and the grid.

7.9.1 Determining original plate camera position

When a stock plate is used and the original shooting and set-up documentation is not available it may be necessary to determine the original plate camera position relative to the background scene in order to satisfactorily blend the perspective of the foreground with that of the background.

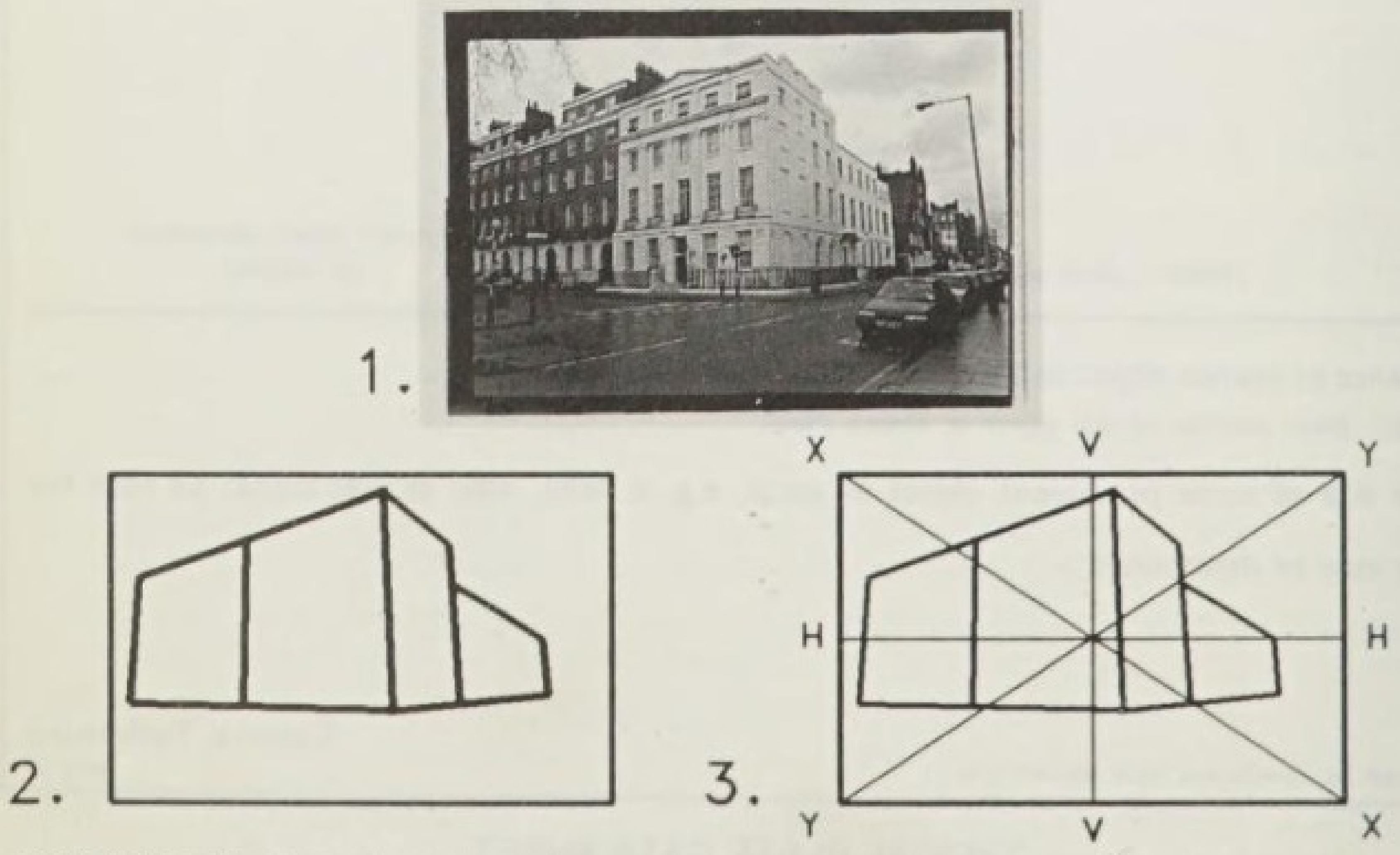
When a camera is pointed at a subject, the lens focal length (lens angle), the camera to subject distance, the lens height above the ground, whether the camera is tilted up or tilted down (angle of inclination) and whether or not it was level with the horizon (angle of cant or twist) all have a bearing on the image and are known as its 'station'. The position of the camera is known as its station point.

By having a photographic print made from a single frame and then applying some elementary drawing board or CAD techniques it is usually a comparatively simple task to recall what was the original camera set-up. The chosen frame should be uncropped and incorporate sufficient objects and buildings with sides or walls at 90° to one another to give the necessary clues. The print should be untrimmed. For most operations only the barest outlines of the object(s) need be drawn or transferred to the computer to deduce all the required information.

The following methods are the most simple and basic but will suffice in a large percentage of cases where no shooting data exists. More complicated drawing techniques must be applied if the plate camera lens had not been centered for the full frame, or if a perspective lens or a rise and fall front or a swing back had been used or if the picture was cropped or trimmed in the enlarging.

7.9.2 Finding the center of vision

The center of vision in an untrimmed photograph is the geometric center of the print. To find it, all that is necessary is to draw lines XX and YY from opposite corners. Where they cross is point C. Lines HH and VV should be drawn passing through point C and parallel with the edges of the frame.



FINDING THE CENTER OF VISION: 1. The original photograph, 2. The periphery of the image and the barest outline of the principal objects are delineated, 3. The center of vision and the horizontal and vertical center lines are drawn.

7.9.3 Finding the focal distance, the horizontal and vertical lens angles and the lens focal length

The focal distance may be determined from an untrimmed photograph of a scene which incorporates a right-angled object, i.e. two walls of a building or two buildings set at 90° to one another. Upper and lower horizontal lines forming parts of such objects can be extended until they meet and become known as vanishing points (VP). (If a line is drawn between vanishing points on either side of the picture which passes through point C then there was no camera tilt when the picture was taken. If it is coincident or parallel with line HH then there was no camera cant or twist when the picture was taken.)

The vanishing points of two planes set at 90° to one another, LVP and RVP, are drawn and projected down to a line drawn below and parallel to the bottom of the picture. These points are known as VP^1 and VP^2. The left- and right-hand edges of the photograph and the center of vision are also projected down to this line and known as A, B and C^1. The point C^1 is equidistant between A and B.

The line VP^1 - VP^2 is bisected and this point is known as point O. A semi-circle, with its center at point O is drawn between VP^1 and VP^2.

A perpendicular line is drawn from point C^1 until it meets the semi-circle at point S. The length of this line, SC^1, is the focal distance and the angle ASB is the horizontal lens angle.

The vertical lens angle can be found by drawing a similar line at the side of the picture and drawing a line the same length as SC^1 perpendicular to the center. The angle $A^1S^1B^1$ is the vertical camera angle.

If the width of the image and the angle are known the lens focal length can be calculated:

$$\textit{Focal length} = \frac{Imagewidth}{2\tan(lensangle^\circ \div 2)}$$

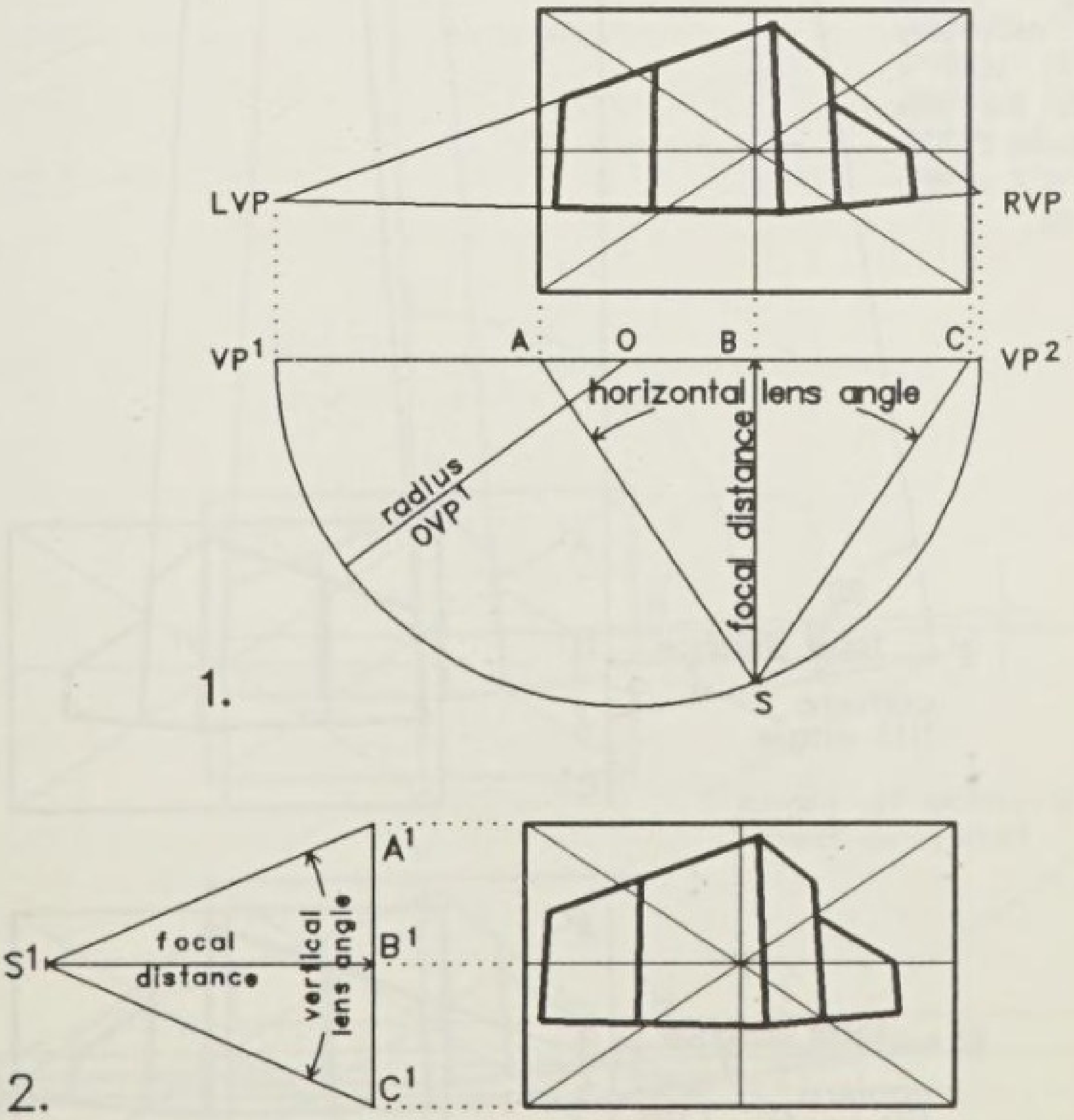
or

$$f = I/(2^*(\mathrm{TAN}(L°/2)))$$

or where the computer operates only in radians:

$$f = I/(2^*(\mathrm{TAN}(L°{}^*0.0174533/2)))$$

where f = Focal length, I = Image width or height and L° = Lens angle



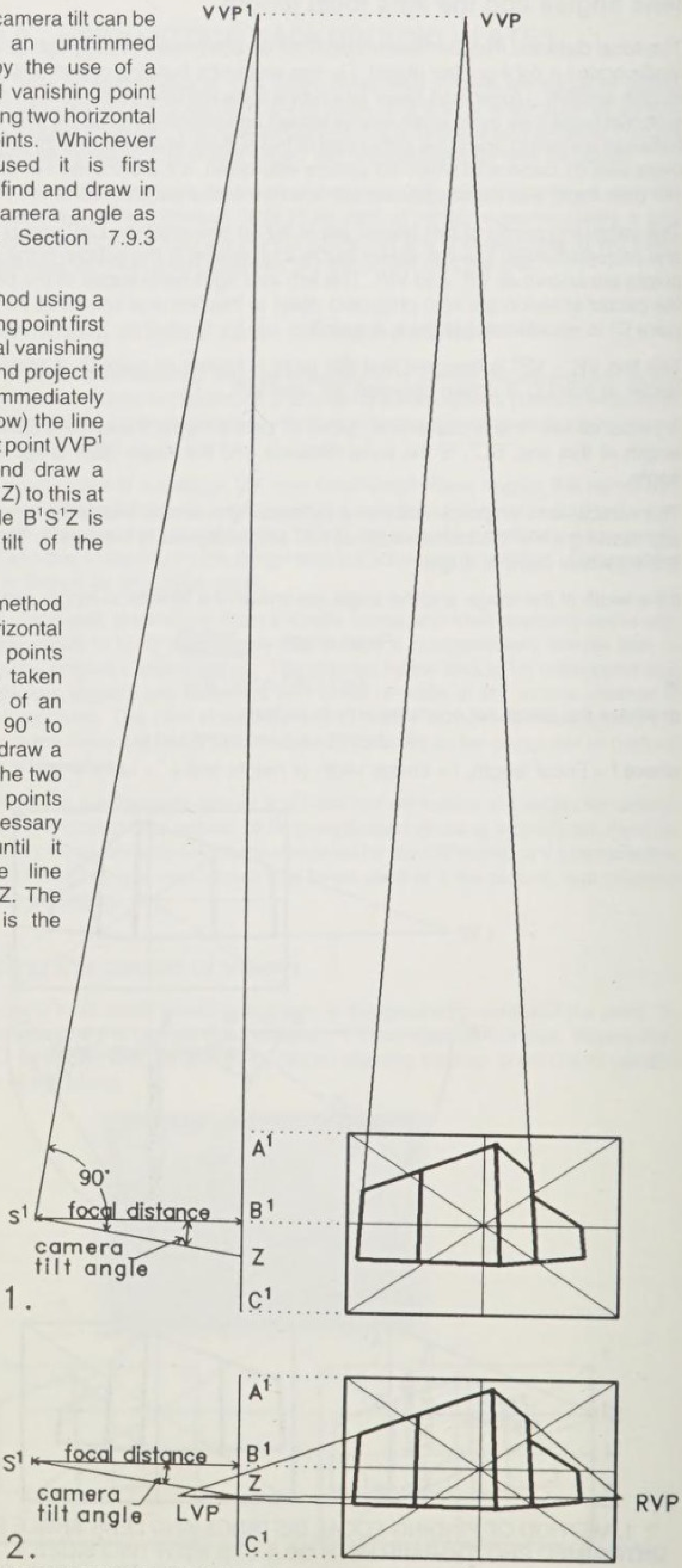
1. METHOD OF FINDING FOCAL DISTANCE AND LENS ANGLE FROM AN UNTRIMMED PHOTOGRAPH WITH OBJECTS WITH TWO SIDES AT 90° TO ONE ANOTHER; 2. METHOD OF FINDING THE VERTICAL LENS ANGLE.

7.9.4 Finding the Angle of camera Tilt

The angle of camera tilt can be found from an untrimmed photograph by the use of a single vertical vanishing point or by connecting two horizontal vanishing points. Whichever method is used it is first necessary to find and draw in the vertical camera angle as described in Section 7.9.3 above.

To use a method using a single vanishing point first find the vertical vanishing point (VVP) and project it to the side immediately above (or below) the line A^1C^1. Connect point VVP^1 to point S^1 and draw a further line (S^1Z) to this at 90°. The angle B^1S^1Z is the upward tilt of the camera.

To use a method using two horizontal vanishing points (LVP & RVP) taken off two sides of an object set at 90° to one another, draw a line between the two vanishing points (and if necessary extend it) until it intersects the line A^1B^1 at point Z. The angle B^1S^1Z is the angle of tilt.



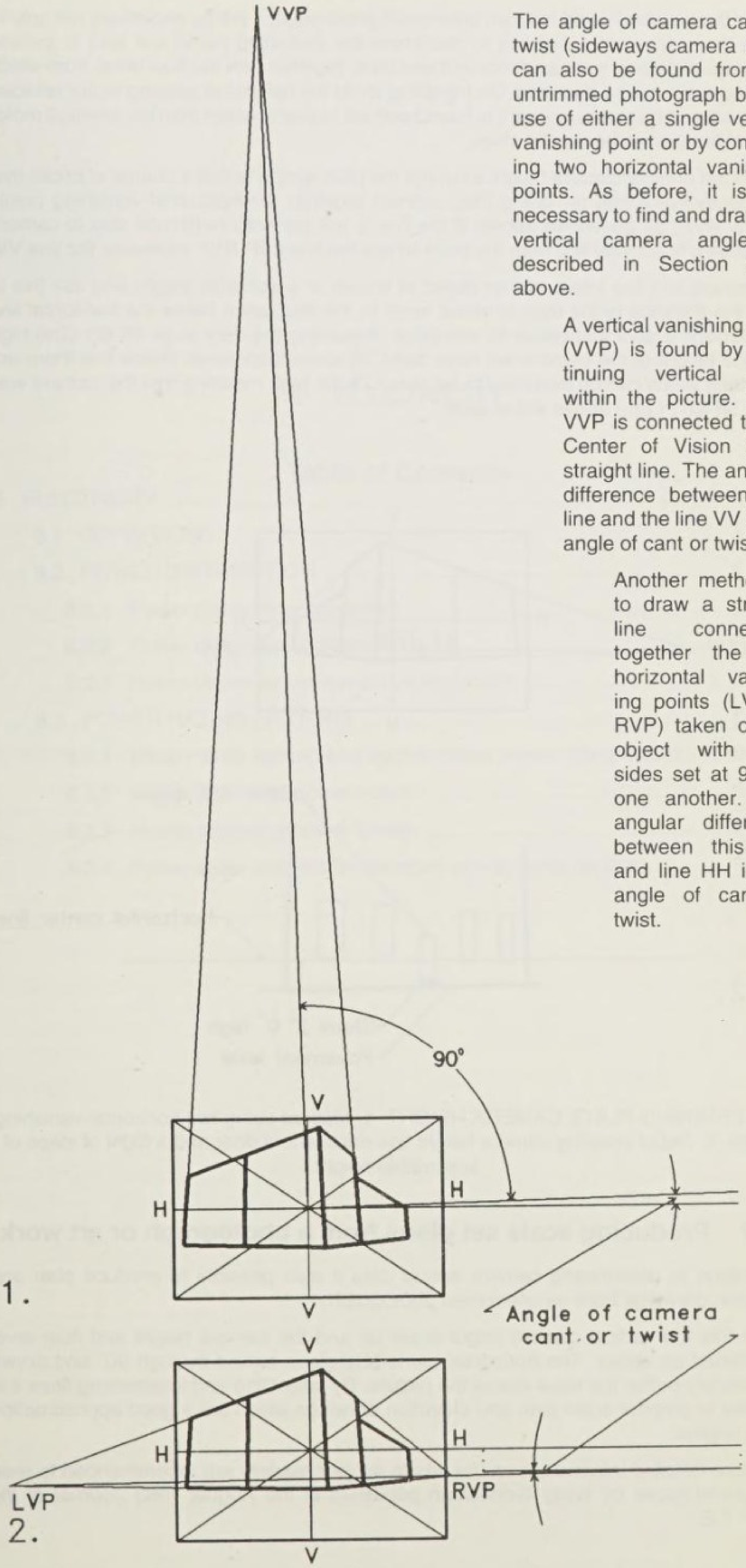
METHOD OF DETERMINING CAMERA TILT: 1. By using a single vertical vanishing point, 2. By using a two horizontal vanishing points.

7.9.5 Finding the angle of cant or twist

The angle of camera cant or twist (sideways camera level) can also be found from an untrimmed photograph by the use of either a single vertical vanishing point or by connecting two horizontal vanishing points. As before, it is first necessary to find and draw the vertical camera angle as described in Section 7.9.3 above.

A vertical vanishing point (VVP) is found by continuing vertical lines within the picture. Point VVP is connected to the Center of Vision by a straight line. The angular difference between this line and the line VV is the angle of cant or twist.

Another method is to draw a straight line connecting together the two horizontal vanishing points (LVP & RVP) taken off an object with two sides set at 90° to one another. The angular difference between this line and line HH is the angle of cant or twist.



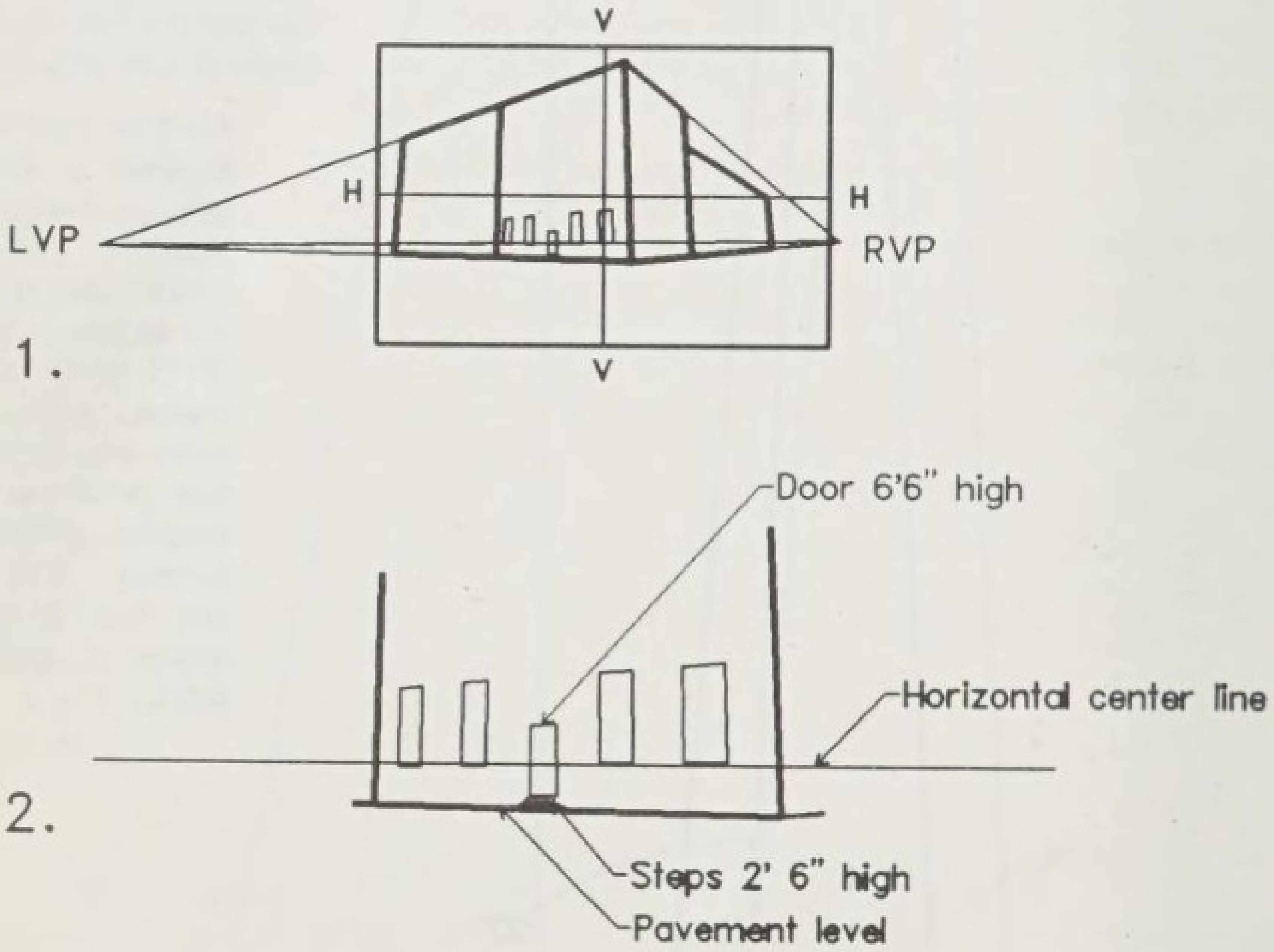
DETERMINING CAMERA CANT: 1. By using a single vertical vanishing point, 2. By using two horizontal vanishing points.

7.9.6 Determining plate camera height

To find the camera height from an untrimmed photograph it will be necessary not only to define the outlines of a building to determine the vanishing points but also to include architectural details, such as doors and windows, together with the floor level, from which size and scale can be deduced. On travelling shots the heights of passing motor vehicles and whether the camera appears to have been set higher or lower than the average motor car roof level are other useful clues.

To find the original camera height examine the photograph to find a course of bricks that is perfectly horizontal or, failing this, connect together the horizontal vanishing points (LVP & RVP) as described above. If the line is not perfectly horizontal due to camera cant draw a horizontal line from the point where the line LVP RVP intersects the line VV.

Note where this line intersects an object of known or assumable height and use this to scale the distance to the floor or street level. In the illustration below the horizontal line cuts through a door just below its mid-point. Assuming the door to be 6ft 6in (2m) high then the height of the camera will have been 3ft above floor level. Below this there are four steps which can be assumed to be about 2ft 6in high meaning that the camera was about 5ft 6in (1.8m) above street level.



DETERMINING PLATE CAMERA HEIGHT: 1. Method using two horizontal vanishing points, 2. Detail showing camera height line relative to a door and a flight of steps of assumable height.

7.9.7 Producing scale set plans from a photograph or art work.

In addition to determining camera set-up data it also possible to produce plan and elevation drawings from an untrimmed photograph.

To do this the vertical camera angle is set up and the camera height and floor level determined as above. The horizontal camera angle is turned through 90° and drawn immediately below the base line of the picture. By projecting and intersecting lines it is possible to prepare scale plan and elevation drawings which are a good approximation of the original.

For more detailed information on this whole subject readers are recommended to read the tutorial paper by Wally Gentleman published in the August 1963 *Journal of the S.M.P.T.E.*

8 ELECTRICITY

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WARNING:

ELECTRICITY IS DANGEROUS AND CAN KILL. IT SHOULD ALWAYS BE TREATED WITH RESPECT.

ALL OPERATIONS INVOLVING ELECTRICITY SHOULD ONLY BE CARRIED OUT BY PROPERLY QUALIFIED PERSONNEL.

THE LOGISTICS OF POWER SUPPLIES FOR FILM AND TELEVISION LIGHTING ARE OFTEN COMPLEX AND MUCH CONTROLLED AND INFLUENCED BY LOCAL RULES AND REGULATIONS AS WELL AS BY THE NEEDS AND CIRCUMSTANCES OF THE JOB IN HAND. FOR ALL OF THESE REASONS ANY INFORMATION RELATING TO THE USE OF ELECTRICITY AND OF ELECTRICAL EQUIPMENT CONTAINED IN THIS BOOK SHOULD BE TAKEN ONLY AS A GUIDE.

The following is intended only as a practical guide to film and television location lighting working practices. It has no relevance to permanent installations in domestic or industrial premises.

8.1 DEFINITIONS

Alternating Current (AC). Current which varies in direction and magnitude.

Ampere (A). The unit of electric current. (Symbol *I*.)

Candela (cd). The international unit of luminous intensity. (Symbol *I*.)

Cycle. One complete set of changes on an DC waveform.

Direct Current (DC). Current which flows in a single direction.

Eddy current. The current induced into a magnetic core by mutual inductance.

Electromotive force (e.m.f.). The voltage measured across a source of supply when no current is flowing (open-circuit voltage).

Frequency (f). The number of cycles completed in a second, for example 50 or 60 cycles per second. (Unit: *Hz*.)

Henry (H). The unit of inductance

Impedance (Z). The opposition to a flow of alternating current in a circuit. (Unit: *ohm*.)

Joule (J). A unit of electrical energy.

Kilowatt-hour (kWh). The practical unit of electrical energy.

Lumen. The unit of luminous flux which is the light emitted from a source. (Symbol: *F*.)

Ohm's Law. States that the current (*I*) flowing in a circuit is directly proportional to voltage (*V*) and inversely proportional to resistance (*R*), at a constant temperature.

Ohm (Ω). The unit of resistance.

Potential difference (p.d.). The voltage measured across a circuit, or part of a circuit, when a current is flowing (the closed-circuit voltage).

Power factor (p.f.). The ratio between true power (kW) and apparent power (kVA).

Resistivity. The resistance of a standard unit area of a standard unit length of a material measured across opposite faces of the unit. In the U.S.A. the unit is a cylinder 1 circular-mil in diameter and 1 foot long, Internationally it is a cube 1 centimeter × 1 centimeter × 1 centimeter. In the U.S.A. the resistivity of copper is given as 10.4 Ohms per circular-mil foot and internationally as 1.7 microhm-cm (a microhm is one millionth of an ohm). (Symbol: ρ, the Greek letter rho).

Root mean square (r.m.s.) value. That value of alternating voltage, or current, which gives the same heating or lighting as a similar value of direct voltage, or current. Supply voltages are always given in r.m.s. values. Peak or Maximum value is the highest value which an alternating voltage or current achieves over a half cycle and is 1.414 times the r.m.s. value.

Temperature coefficient. The temperature coefficient of a material is the increase in the resistance of a one ohm resistor of that material when it is subjected to a rise in temperature of 1°C. The temperature coefficient of copper is 0.004 ohm per ohm per °C. (Symbol: Greek letter α (alpha).)

Volt (V). The unit of electric pressure. (Symbol: V or E.)

Watt (W). The unit of electric power. (1000W = 1kW.)

8.2 POWER DISTRIBUTION

Before lamps can be put into operation electric power has to be delivered to them. The pre-planning and execution of the type of temporary power supply network for a major film set or television remote, where there are multitude of lamps spread over a considerable area, is a highly skilled and responsible job for qualified personnel.

The first requirements are to know what is the maximum likely power demand (in watts or kilowatts), where it is to be deployed and the source of the power supply.

If any of the lamps are of the Metal Halide discharge type (HMI etc.) then an AC supply will be necessary and if carbon arc lamps are to be used then there must be a DC supply. If the lamps use only tungsten halogen bulbs then either an AC or a DC supply will be suitable. If high power HMI lamps are to be used the power supply may have to be in excess of 200 volts, which means using 3-phase (208 volts) in a 120 volt 1-phase country.

To calculate the total load add together the wattage of all lamps that could possibly be lit at any one time, adding on a little over 10% to the Metal Halide lamps, and divide this total by the voltage to get the total amperage. (See Section 15.2.8 for more information.)

A decision will then have to be taken as to whether to take the power supply from the mains or from portable AC alternators or DC generators.

If from the mains then the question arises that for the amount of current required will it have to be taken as three phase or single phase. If three phase then, unless a high voltage supply is what is required, it will be necessary to split the phases into 3 × 1–phase supplies and spread the load more or less equally over all three phases, keeping discreet areas of lighting confined to a particular phase supply. Local safety regulations may stipulate that there be a minimum distance between units powered by different phases.

If alternators or generators are to be used then they should be parked as close to the shooting location as possible to minimize the length of cable run to allow as light a cable as possible to be used while still keeping the voltage drop within the allowed percentage (usually 2%). The longer the cable run the thicker and heavier the cable needs to be. The choice of minimum cable size will also influenced by the ambient temperature and whether there is air space between the individual cores or whether it is a multi-core cable. (See Section 15.2 for more information.)

If sync sound is being shot the noise level of the portable power supply will have to be taken into consideration. It may be best to park a noisy mobile alternator or generator down-wind and behind brick walls.

In all cases, and most particularly if a three phase supply is being used, there must be an accessible multi-phase, multi-pole isolating switch which in an emergency can be used to disconnect all electric power from the entire system.

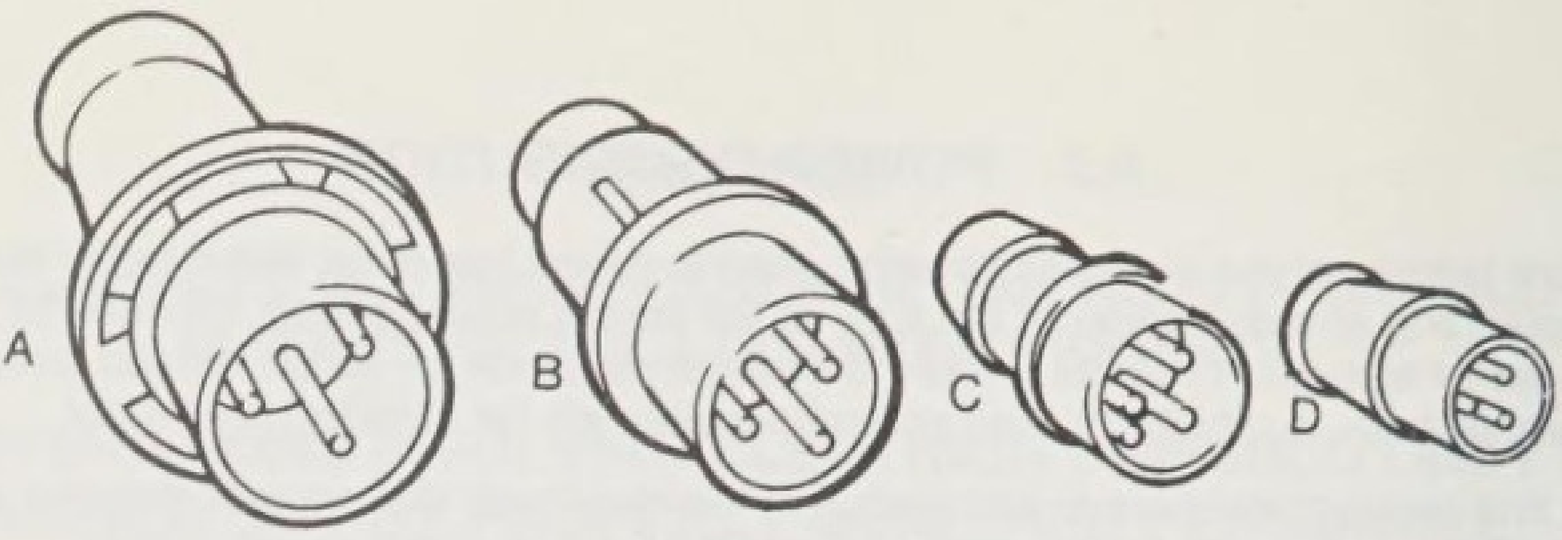
8.2.1 Power distribution equipment

There is no standardized or universal power distribution system, or even equipment, used anywhere in the world. Every country, and every state, and every local authority has its own rules and regulations and every lighting power supply company has its own equipment to interpret the rules in its own manner.

The following description is of a safe and efficient system and the one best known to the author. It is included only as a guide to what is allowed and used in one part of the world. The system is that used by Michael Samuelson Lighting Ltd. of Pinewood Studios, England and conforms to BS 5550 subsection 7.5.1 of 1981.

Development of the system commenced in the 1970s with the introduction of HMI lighting which required a 220–240 volt 1–phase AC power supply for the smaller lamps (up to 2.5kW) and 380–415 volts 3–phase for the 4000 watt type, then the largest HMI lamp available. It was quite obvious that the open ended box type stage plugs, big enough for a child to stick its fingers into, bus-bar boxes with ill-fitting flexible flaps and high amperage cables with uncovered lugs on them, all with inadequate provision for polarity control and automatic grounding, could not be used safely with AC voltages of this magnitude. A whole new system had to be designed and implemented.

The first requirement was to decide upon a suitable plug and socket system. This was found, readily available, standardized and approved, 'shower proof', well tried and tested, inexpensive, and in daily use, in the construction industry. There were even three distinct non-interchangable 'families' of plugs and sockets, yellow ones for low voltage, blue for standard 1–phase and red for 3–phase. After twenty years of usage, by many companies and in many countries, these plugs and sockets, which conform to BS 4343, have been found to be an ideal solution.



BS4343 1–PHASE PLUGS: A. 125 amp; B. 63 amp; C. 32 amp; D. 16 amp.

There are two MSL power distribution systems, the '125', which can handle a total load of up to 125 amps and is suitable for most single stage and location purposes, and the Type '400' for major film and TV productions where up to 400 amps needs to be handled. Both systems can take in and split 3-phase power but the System 400 can be used with higher ampere single core cables and has more 3-phase handling and distribution capability than the smaller system. A complementary '150' system, and/or the '125' system, can be used for subsidiary distribution in conjunction with the larger system.

Both systems are modular (only those units needed for a particular set-up need be deployed) and stackable (units can be stacked one on top of another, either for convenience or to isolate them from a wet ground surface).

The '125' comprises the following units:

125 and 63 amp 3-phase Isolation switch units.

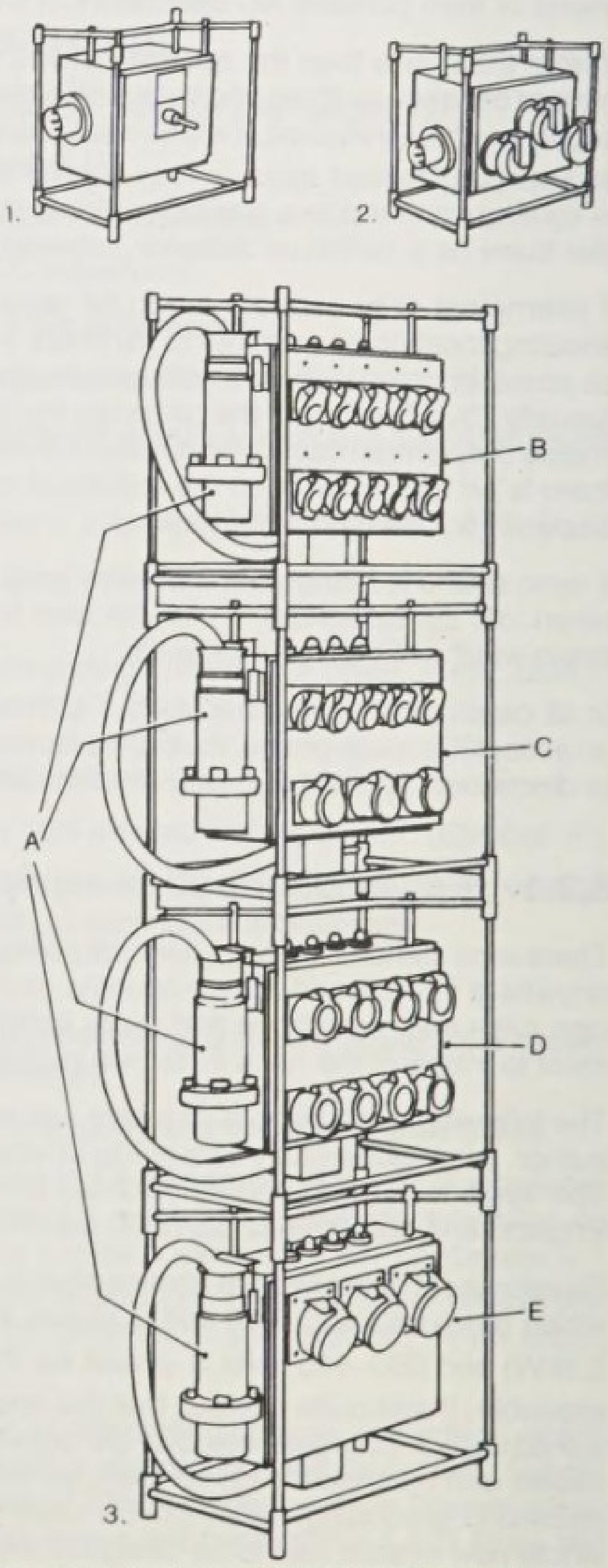
125 and 63 amp 3-phase to 1-phase splitter units.

125 amp to 3 × 63 amp, or 8 × 32 amp, or 3 × 32 + 5 × 16 amp or 10 × 16 amp outlet socket power distribution units.

Each of these power distribution units incorporates a double-pole isolator switch which can be locked in the OFF position, each outlet has an individual neon indicator, a mechanical (not thermal) circuit breaker (which trips automatically if there is an overload or a short circuit) and a circuit breaker for the neutral pole which can be used for testing purposes or to disconnect the neutral pole in case of damage to any outlet or in-line connector.

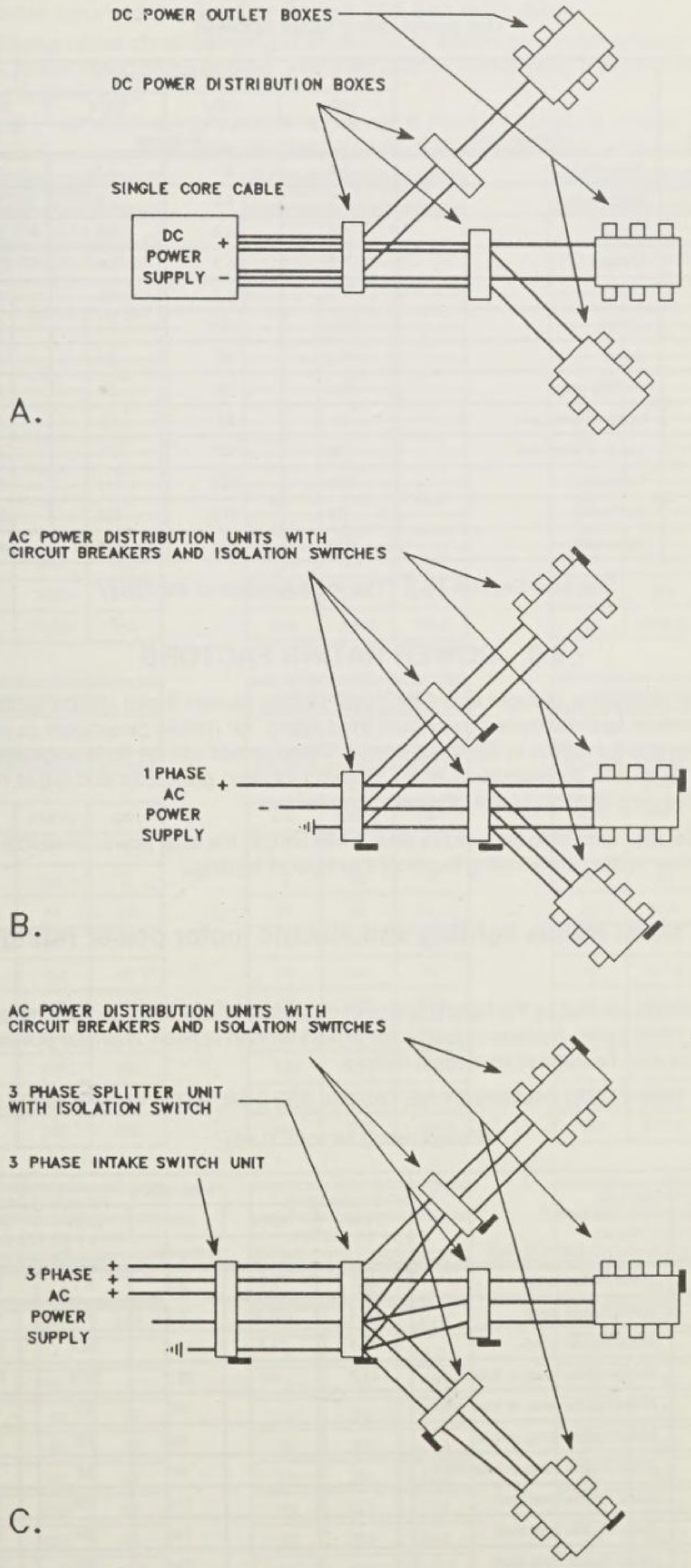
On the top of each unit are four colored lights to indicate the state of the system. A lit green light indicates that the unit is properly grounded, a red light warns of reverse polarity and a flashing blue light and a buzzer indicate when there is a ground leakage on any unit. The buzzer is a particularly useful safety measure as its sound can be heard when a faulty lamp or other unit is plugged in, even if the flashing blue indicator lamp is out of sight. As the system is also used for live TV broadcasts the buzzer can be isolated by a key switch, in which case an amber lamp lights to indicate that this is so. Normally, only the gaffer has the key to switch off the ground leakage warning buzzers.

Additional units which form a part of the system are ground leakage circuit breaker units in all four ampere ratings in the system, 125 and 63 amp cable splitter boxes, 63 and 32 amp distribution units, 'Y' cords, jumper leads and converter outlets for domestic type plugs, etc.



MSL ELECTRIC POWER DISTRIBUTION SYSTEM: 1. '125' ISOLATOR SWITCH UNIT, 2. '125' 3-PHASE SPLITTER UNIT, 3. STACKED '125' DISTRIBUTION UNITS: A. 125 amp 1-phase inlet plugs on short cables; B. 10 × 16 amp outlets; C. 5 × 16 + 3 × 32 amp; D. 8 × 32 amp; E. 3 × 63 amp.

8.2.2 Power distribution schematics


DC POWER OUTLET BOXES
DC POWER DISTRIBUTION BOXES
SINGLE CORE CABLE
DC POWER SUPPLY
+
−
A.
AC POWER DISTRIBUTION UNITS WITH CIRCUIT BREAKERS AND ISOLATION SWITCHES
1 PHASE AC POWER SUPPLY
+
−
B.
AC POWER DISTRIBUTION UNITS WITH CIRCUIT BREAKERS AND ISOLATION SWITCHES
3 PHASE SPLITTER UNIT WITH ISOLATION SWITCH
3 PHASE INTAKE SWITCH UNIT
3 PHASE AC POWER SUPPLY
+
+
+
C.

POWER DISTRIBUTION SCHEMATICS: A. DC, B. 1–phase AC, C. 3–phase AC.

8.2.3 Power drawn by various lamps and loads

POWER (AMPERES) DRAWN BY TUNGSTEN HALOGEN LIGHTING

(No power rating factor applied)

Wattage	Lamp or load	Power supply			
		110V	120V	220V	240V
		Amperes			
375	Photoflood	3.4	3.1	1.7	1.6
500	Baby or pup	4.5	4.2	2.3	2.1
650	Lamp	5.9	5.4	3.0	2.7
800	Lamp	7.3	6.7	3.6	3.3
1000	Lamp	9.1	8.3	4.5	4.2
2000	Lamp	18.2	16.7	9.1	8.3
5000	Lamp	45.5	42	23	21
5850	9 x 650 watt	53.2	49	27	25
10,000	Lamp or total load	91	84	46	42
20,000	Lamp or total load	182	167	92	84
25,000	Total load	228	209	114	105
50,000	Total load	455	417	228	209
100,000	Total load	910	834	455	417

See also Section 15.2, 'The mathematics of electricity'.

8.3 POWER RATING FACTORS

Additional resistance brought about by many factors causes Metal Halide lighting and electric motors to draw more power than their rating, for mobile generators to produce less power and for cables to dissipate power. These losses can be quite substantial and must be taken into consideration when planning location generator and cable requirements. See also Section 15.2.4, 'Power rating factors'.

If a mobile alternator is to be used to power MH lamps, the total power available will be reduced due to the power rating factor of this type of lighting..

8.3.1 Metal Halide lighting and electric motor power rating factors

The resistance caused by the ballast unit causes Metal Halide lamps to draw more power than their rated value. A power rating factor of 0.85 is often applied. A similar power rating factor must also be applied to electric motors.

POWER (AMPERES) DRAWN BY METAL HALIDE (HMI, ETC.) LAMPS AND LOADS

(Power rating factor = 0.85)

Wattage	Lamp or load	Power supply				
		110V	120V	208V	220V	240V
		Amperes				
575	Metal Halide lamp	6.2	5.7	3.3	3.1	2.8
1250	Metal Halide lamp	13.4	12.3	7.1	6.7	6.1
2500	Metal Halide lamp	26.8	24.6	14.2	13.4	12.3
4000	Metal Halide lamp or total load	42.9	40	22.7	21.5	19.7
8000	Metal Halide lamp or total load			46	43	40
12,000	Metal Halide lamp or load			68	65	59
16,000	Metal Halide lamp or total load			91	86	79
20,000	Metal Halide total load			114	108	99
25,000	Metal Halide total load			142	134	123
50,000	Metal Halide total load			284	268	246
100,000	Metal Halide total load			568	536	492

8.3.2 Mobile alternator power output

The power of AC alternators are sometimes rated in kVA units which take the power rating factor into consideration. See Section 15.2.2 for more details.

The following tables show the rating of an alternator with no power rating factor and with an 85% power rating factor applied. The third column shows what alternator is needed to power a given load.

TABLE 1. MOBILE ALTERNATOR AVAILABLE POWER (SINGLE PHASE, WITH 0.85 POWER RATING FACTOR APPLIED).

TRUE POWER		
120 VOLTS 1 φ AC		
POWER RATING FACTOR = 1		
kW	AMPS	kVA
1	8	1
5	42	5
10	83	10
20	167	20
40	333	40
60	500	60
80	667	80
100	833	100
120	1000	120
160	1333	160

AVAILABLE POWER		
120 VOLTS 1 φ AC		
POWER RATING FACTOR = 0.85		
kW	AMPS	kVA
1	9	1.2
5	45	5.9
10	90	11.7
20	181	23.6
40	362	47.1
60	542	70.5
80	723	94.1
100	904	117.7
120	1085	141.2
160	1446	188.2

NEEDED POWER		
120 VOLTS 1 φ AC		
POWER RATING FACTOR = 0.85		
kVA	AMPS	kW
1	7.7	0.9
5	38.4	4.2
10	76.8	8.5
20	153.7	17
40	307.3	34
60	461	51
80	614.6	68
100	768.3	85
120	922	102
160	1229.3	136

TRUE POWER		
220 VOLTS 1 φ AC		
POWER RATING FACTOR = 1		
kW	AMPS	kVA
1	5	1
5	23	5
10	45	10
20	91	20
40	182	40
60	273	60
80	364	80
100	455	100
120	545	120
160	727	160

AVAILABLE POWER		
220 VOLTS 1 φ AC		
POWER RATING FACTOR = 0.85		
kW	AMPS	kVA
1	5	1.2
5	25	6
10	49	11.7
20	99	23.6
40	197	47
60	296	70.6
80	394	94
100	493	117.6
120	592	141.3
160	789	188.3

NEEDED POWER		
220 VOLTS 1 φ AC		
POWER RATING FACTOR = 0.85		
kVA	AMPS	kW
1	4.2	0.9
5	21	4.3
10	41.9	8.5
20	83.8	17
40	167.6	34
60	251.4	51
80	335.3	68
100	419.1	85
120	502.9	102
160	670.5	136

TRUE POWER		
240 VOLTS 1 φ AC		
POWER RATING FACTOR = 1		
kW	AMPS	kVA
1	4	1
5	21	5
10	42	10
20	83	20
40	167	40
60	250	60
80	333	80
100	417	100
120	500	120
160	667	160

AVAILABLE POWER		
240 VOLTS 1 φ AC		
POWER RATING FACTOR = 0.85		
kW	AMPS	kVA
1	5	1.3
5	23	6
10	45	11.7
20	90	23.4
40	181	47.1
60	271	70.5
80	362	94.2
100	452	117.7
120	542	141.1
160	723	188.2

NEEDED POWER		
240 VOLTS 1 φ AC		
POWER RATING FACTOR = 0.85		
kVA	AMPS	kW
1	3.8	0.8
5	19.2	4.2
10	38.4	8.5
20	76.8	17
40	153.7	34
60	230.5	51
80	307.3	68
100	384.1	85
120	461	102
160	614.6	136

8.3.3 Mobile alternator power losses

If a mobile alternator is to be used at high altitude or in conditions of high ambient temperature it will produce less power than under normal circumstances. (See also Section 15.2.4.

TABLE 2. MOBILE ALTERNATOR/GENERATOR LOSS OF POWER DUE TO ALTITUDE

Altitude		Alternator/generator rated output at sea level (Amps)										
		50	100	200	300	400	500	600	700	800	900	1000
Meters	Feet	Alternator/generator output at altitude (Amps)										
305	1000	49.1	98	197	295	393	491	590	688	786	884	983
460	1500	48.3	97	193	290	386	483	579	676	772	869	966
610	2000	47.5	95	190	285	380	475	570	665	759	854	949
760	2500	46.7	93	187	280	373	467	560	653	747	840	934
915	3000	45.9	92	184	276	367	459	551	643	735	827	918
1220	4000	44.4	89	177	266	355	444	533	621	710	799	888
1525	5000	43	86	172	258	344	430	516	602	688	774	859
1830	6000	41.7	83	167	250	334	417	501	584	668	751	835
2135	7000	40.5	81	162	243	324	405	486	567	648	729	810
2440	8000	39.4	79	157	236	315	394	472	551	630	709	787

Table 3. Mobile alternator humidity/temperature power loss

Atmospheric Temperature		**Relative humidity (%)**								
		20	30	40	50	60	70	80	90	100
°F	**°C**	**Percentage derating**								
86	30				0.1	0.6	1.2	1.7	2.2	2.7
90	32				0.4	1.0	1.6	2.1	2.7	3.3
93	34			0.1	0.8	1.4	2.1	2.7	3.3	4.0
97	36			0.4	1.2	1.9	2.6	3.3	4.0	4.7
100	38			0.8	1.6	2.4	3.1	3.9	4.7	5.5
104	40		0.2	1.1	2.0	2.9	3.8	4.7	5.5	6.4
108	42		0.5	1.5	2.5	3.5	4.5	5.4	6.4	7.4
111	44		0.9	2.0	3.0	4.1	5.2	6.3	7.4	8.5
115	46		1.2	2.4	3.6	4.8	6.0	7.3	8.5	9.7
118	48	0.3	1.6	2.9	4.3	5.6	7.0	8.3	9.6	11.0
122	50	0.6	2.0	3.5	5.0	6.4	7.9	9.4	10.9	12.4
126	52	0.9	2.5	4.1	5.8	7.5	9.0	10.6	12.3	13.9

8.3.4 Power cable ambient temperature power rating factors

The resistance of a conductor increases with ambient temperature (see Section 15.2.5.3) and to compensate for this a power rating factor must be applied when cables are laid out in conditions of excessive heat.

The current carrying capacity of cables will differ according to the specification of the insulation and sheathing and in all cases the manufacturers recommendations must be adhered to. As a general guide, cables which are rated for normal use at 85°F or 30°C might expect to have the following power rating factors applied when used in higher ambient temperature conditions.

TABLE 4. POWER CABLE CORRECTION FACTORS FOR HIGH AMBIENT TEMPERATURES

(Typical 85°C rubber insulated cable, two-core, up to 4AWG or $25mm^2$)

Ambient Temperature	86°F 30°C	95°F 35°C	104°F 40°C	113°F 45°C	122°F 50°C	131°F 55°C	140°F 60°C	150°F 65°C
Correction factor	1.0	0.95	0.9	0.85	0.80	0.74	0.67	0.60

9 EQUIPMENT CHECK LIST

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This list is intended as an *aide-mémoire* to all who have the responsibility for budgeting for, or ordering, preparing and using the technical equipment necessary to make a motion picture.

9.1 CAMERA EQUIPMENT

Cameras

- 65, 35 or 16mm
- back-up
- handholdable
- high speed
  - upto 100 fps
  - upto 120 fps
  - upto 360 fps
  - upto 500 fps
  - more than 500 fps
- plate
- principal
- process
- publicity unit
- reverse running
- 2nd unit
- single shot
- studio quiet
- sync
- Super 35
- Super 16
- Techniscope
- three perf
- Vistavision
- wild

9.2 CAMERA FACILITIES

- Adjustable shutter
  - while camera running
  - while camera stopped
- aperture plate
  - 16mm
    - regular
    - Super 16
  - 35mm
    - academy
    - anamorphic
    - full frame
    - wide screen
      - 1.66:1
      - 1.85:1
- ground glass markings
  - 16mm
    - regular
    - Super 16
    - TV transmitted area
      - with safe action area
  - 35mm
    - Academy
      - with TV transmitted area
      - with 1.66 or 1.85:1 wide screen
    - anamorphic
      - with 70mm
    - full frame
    - Super 35
      - with Academy
      - with 2.35:1 (for anamorphic print)
      - with TV
      - with 1.66 or 1.85:1 wide screen
    - TV transmitted area
      - with safe action area
    - with/without center cross
- required or maximum shutter opening
  - 200°
  - 180°
  - 172.8°
  - 165°
  - 144°
- motor type
  - battery
  - clockwork
  - mains
- reflex system
  - beamsplitter
  - rotating mirror
- register pin
- reverse running
- sync pulse generator
- through-the-lens exposure meter
  - automatic aperture control
  - manual aperture control
- viewfinder system features
  - anti-misting
  - contrast viewing filter
  - de-anamorphosing
  - extendable eyepiece
  - heated eyepiece
  - illuminated ground glass markings
  - image magnification
  - light cut-off shutter
  - linkage to pan/tilt head
  - night sight facility
  - orientatible
  - swing-over
  - video (see Video Viewfinder in Camera Accessories section)

9.3 CAMERA ACCESSORIES

- Automatic fade unit
- barnies
  - heater
    - camera body
    - lens
    - magazine
  - sound proof
  - weather proof
    - with rain deflector
  - white
- batteries
  - additional
  - belt
  - for camera heaters
  - high capacity
  - on-board
  - regular
- battery charger
- beamsplitter mirror
- cables
  - power
  - sync
  - video
- camera mounted lamp
- camera oil
- camera speed checker
- changing bag
- crash helmet with camera mounting
- electronic range finder
- eyepiece extension
- flange focal depth guage set
- follow-focus control
- floating camera system
- frame punch
- french flags and adjustable arms
- gelatine filter cutter
- hand-holding supports
- heaters
  - camera
  - eyepiece
  - lens
  - magazine
- lens controls
  - aperture
  - focus
  - zoom
- lens support
- light box
- light overlay system
  - front-of-lens
  - internal
- magazines
  - 1200 ft.
  - 1000 ft.
  - 500 ft.
  - 400 ft.
  - 250 ft.
  - 200 ft.
  - bipack
  - high speed
  - reverse running
- matte box
  - filter trays
    - for 1 filter
    - for 2 filters
    - for 3 filters
    - for circular filters
    - rotating
    - sliding
    - tiltable
  - top flap
- motor adaptor
- motors (additional or special)
  - battery
  - clockwork
  - crystal
  - mains sync
  - high speed
  - reversible
  - single shot
  - variable speed
- nodal mounting adaptor
- prompter
- protective covering
- rain deflectors
- remote on/off switch
- remote speed and footage display
- shoulder supports
- spare
  - batteries
  - bobbins (cores)
  - cables
  - fuses
- splash box
- sports finder
- sync pulse cable
- synchronizers
  - to another camera
  - to projector
  - to video
  - to a.c. power source
- tie-downs
- tracking supports
- turnover mount
- unit box
- under water housing
- video phase shifter
- video viewfinder
  - b & w or color
  - CCD type
  - flicker free
  - frameline generator
  - freeze frame facility
  - gen-lock facility
  - image enhancement unit
  - monitor
  - recorder
- viewfinders (other than camera or video)
  - directors
  - Mitchell type
  - night sight
  - orientable
  - periscope
  - sport
  - using camera lens

9.4 EFFECTS EQUIPMENT

Atmospheric effects
- fog
  - general
  - low lying
- lightning
- rain
- snow

motion control equipment
special effects
- back projection
  - projector
  - plates
  - screen
- blue screen
- cloud tank
- front projection
  - projector
    - 65mm
    - 35mm full frame
    - Vistavision
    - still
  - plates
  - screen
- slide projector
  - slides
  - screen

9.5 OPTICAL EQUIPMENT

Dioptres
- .5, .75, 1, 1.5, 2, etc.
- centre spot
- full cover
- split

extension tubes
image stabilizer
lenses
- anamorphic
- macro focusing
- multi-image
- regular
- snorkle
- telephoto
- wide angle
- wide aperture
- zoom

optical accessories
- dove reversing prism
- inclining prism
  - large
  - small
- multi-image lenses
- multi-image prisms
- range extender
- right angle prism
- wide angle attachement

range extenders
remote aperture, focus and zoom controls
- manual
- radio

test charts

9.6 CAMERA FILTERS

Black dot texture screens
blenders
circular polarizer screen
clear (optical flat)
color compensating (CC)
color correction
- amber range
- blue range
- combined with ND

coral range
colored
day for night
diffraction grating
diffusion
fluorescent lighting control
fog
gelatine
- gelatine filter cutter

glass filter
- 2, 3, 4 or 6.6" square
- 4 x 5.650" rectangular
- Series 9 or 10 circular
- other

graduated
- colored
- color balancing (85 etc.)
- neutral density
- diffuser
- star
- with sharp cut-off
- with gradual cut-off

low contrast
nets
- black
- colored
- white

neutral density
optical flats
pola screen
Pro mist
Sepia
star
- various size graticules
- various number of pointed stars

ultra contrast
UV
Vari-Color

9.7 CAMERA SUPPORT EQUIPMENT

- anti-vibration camera mounting
- booms
- car rigs
- crab dollies
- cranes
  - demountable (portable, with remote controlled camera)
  - large (truck mounted)
  - medium (camera crew operation)
  - medium (remote control camera)
  - small (dolly mounted)
- heads
  - fluid
  - friction
  - geared
    - heavy duty
    - lightweight
  - nodal
  - remote controlled
  - sea
  - Trojan helmet
  - turnover
- helicoptor mounts
- hi-hats and risers
- Louma camera crane
- motion controled
  - multi-pass
  - single pass
- spreaders
- spyders
- Steadicam
- tie downs
- tilt plates/wedges
  - adjustable
  - fixed
- tracking vehicles
- tripods

9.8 GRIP EQUIPMENT

- appleboxes (pancakes)
- block board and frames
- camera hide
- car rigs
- dust sheets
- G-clamps
- deals
- dolly track
- head locking jacks
- limpet mounts
- paddle mount
- rostrum (parallel)
- scaffolding and clamps etc.
- suspended camera mounting system
- tarpaulins
- 2-4-6's
- tie down chains and ropes
- umbrella
- wedges
- wood

9.9 EXPENDABLE ITEMS

- aerosols
  - anti flare
  - black wrinkle
  - dust-off etc.
  - foam cleaner
  - lubricant
  - silicone
- black bags or paper
- bobbins (film cores)
  - 2 inch
  - 3 inch
- camera prompter paper
- chalk
- clapper board
  - insert
  - large
  - small
- chinagraph pencils
- cleaning materials
- depth of field calculator
- computer calculator
- dispatch items
  - cases
  - labels
  - string
- empty cans
- eyepiece covers
- film stock
  - 65mm
  - 35mm
  - 16mm
    - single perf
    - double perf
    - mag striped
  - 2000ft - 610m rolls
  - 1200ft - 366m rolls
  - 1000ft - 305m rolls
  - 500ft - 152m rolls
  - 400ft - 122m rolls
  - 200ft - 61m rolls
  - 100ft - 30m rolls
  - 50ft - 15m rolls
  - negative
    - high speed
    - medium speed
    - ultra fine grain
  - reversal
    - high speed
    - slow speed
    - single/double perf.

EXPENDABLE ITEMS, continued

- gelatine filters
- gray scales
- heated clothing
- lab labels
- lab report sheets
- lens cleaning materials
- mag cards
- measuring tape
- meters
  - color temperature
  - light
  - frequency
  - incident
  - reflected light
- pens and pencils
- pen torch
- production stationery
- silica-gel
- tape
  - camera
  - double sided
  - gaffer
  - masking
- viewing glass
- waders
- weatherproof clothing
- wet suits.

9.10 SOUND EQUIPMENT

- batteries
  - microphone
  - recorder
- cables
  - microphone
  - power
  - pulse
- cable accessories
  - adaptors
  - plugs/sockets
  - tails
- head-phones
- loudspeakers
- microphones
  - cardiod
  - directional
  - lavalier (neck)
  - line
  - lip
  - omnidirectional
  - radio
- microphone boom
  - hand (fishpole)
  - studio
- microphone cables
- microphone stand
  - floor
  - table
- tape, adhesive
- mixer unit
- playback equipment
- plug and socket systems - various
- recorder
  - cassette
  - digital (R-DAT)
  - minature
  - sync
  - stereo
  - wild
  - with time code
- recorder stand/trolley
- recording tape
  - 1/4" double play
  - long play
  - R-DAT tape (8mm)
  - standard play
  - 3, 4, 5, 7, or 10.5 dia spools
  - SNN - blue, green or red
- report sheets
- sound blankets
- spare
  - batteries
  - fuses
  - spools
- speed varier
- synchronizer
- synchronizing system
  - crystal
  - mains
  - sync pulse
  - time code
- test meter
- wind shield

9.11 COMMUNICATIONS EQUIPMENT

- amplifier system
- fax machine
- loud-hailer (bullhorn)
- radio telephones
  - inter-unit
  - intra-unit
- red light and bell set
- satellite dish
- telephone
  - cellular
  - normal
- telephone answering machine

9.12 LIGHTING EQUIPMENT

- cables
  - 240 amp
  - 125 amp
  - 64 amp
  - 32 amp
  - 16 amp
  - single core
  - three core
  - three phase
- cable accessories
  - adaptor plugs
  - extension
  - distribution
  - jumper
  - splitter
  - switched
  - tails
- circuit breaker
  - AC
  - DC
- dimmers
  - AC
  - DC
- distribution boxes
- earth (ground) leakage cut-out switch
- generators
  - AC
  - DC
- lamps
  - arc
  - battery portable
  - clip-on
  - color balanced
    - for 3200k
    - for daylight
  - effect spot
  - fluorescent
  - follow spot
  - Metal Halide (HMI, etc.) - 200w
    - 575w
    - 1.2k
    - 2.5k
    - 4k
    - 6k
    - 8k
    - 12k
    - 16k
    - flicker free
    - double ended bulb type
    - single ended bulb type
  - minibrutes
    - 6 x 650w
    - 9 x 650w
  - maxibrutes
    - 9 x 1000w
    - 24 x 1000w
  - photoflood
  - searchlite
  - soft
  - space
  - stobe
  - tungsten
    - less than 1k
    - 1k
    - 2k
    - 5k
    - 10k
    - 20k
  - underwater
- light control
  - black-outs
  - butterflies
  - flags
  - frames for diffusers etc.
  - gobos
  - nets
  - polystyrene holders
  - reflectors
  - scrims
  - silks
- lamp filters
  - color
  - diffusing
- lamp stands
  - regular
  - boom arm
  - hi-lifts
  - century
  - cherry pickers
  - limpets
  - misc. brackets
  - power assisted
  - skates
  - turtles
- meters
  - frequency
  - light
  - test
- power distribution system
  - AC
  - DC
  - HI box
  - spider box
  - single cable connector
- reflectors
- safety chains and ropes
- sandbags
- scaffold towers
- spare fuses
- stage weights
- step ladders
- switching units
- transformers
  - step-down
  - step-up
- window filters
  - color
  - ND

9.13 EDITING EQUIPMENT

- computer editing system
- cuts rack
- edge numbering (coding) machine
- editing bench
- editing machines
  - anamorphic picture
  - spherical picture
  - flat top
  - non-linear (AVID etc.)
  - upright
  - 2, 4 or 6 plate
  - 1 or 2 screens
  - 1 or 2 track
  - video pick-up
  - time code
- film bins
- film horses
- splicers and tape
- projection
  - com-mag
  - com-opt
  - sep-mag
  - picture only
- rewinders
- screen
- sound transfer
- spacing
- spools
  - projector
  - split
- stop watch
- synchronizer amplifier
- synchronizers
  - 2, 3, or 4 head
  - dual guage
  - with picture viewing head
- video editing system

10 EXPOSURE

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When considering the correct exposure for a particular scene the following factors must be taken into account:

Exposure Time (shutter angle and camera speed)

Film Speed (EI)

Lens Aperture (T Stop)

Subject Factors (the reflectance ratio of the most important picture areas, lighting intensity and contrast, scene luminance range etc.).

The desired grain structure

Selected optimum printer lights

The desired 'look' of the final image when properly projected on a screen.

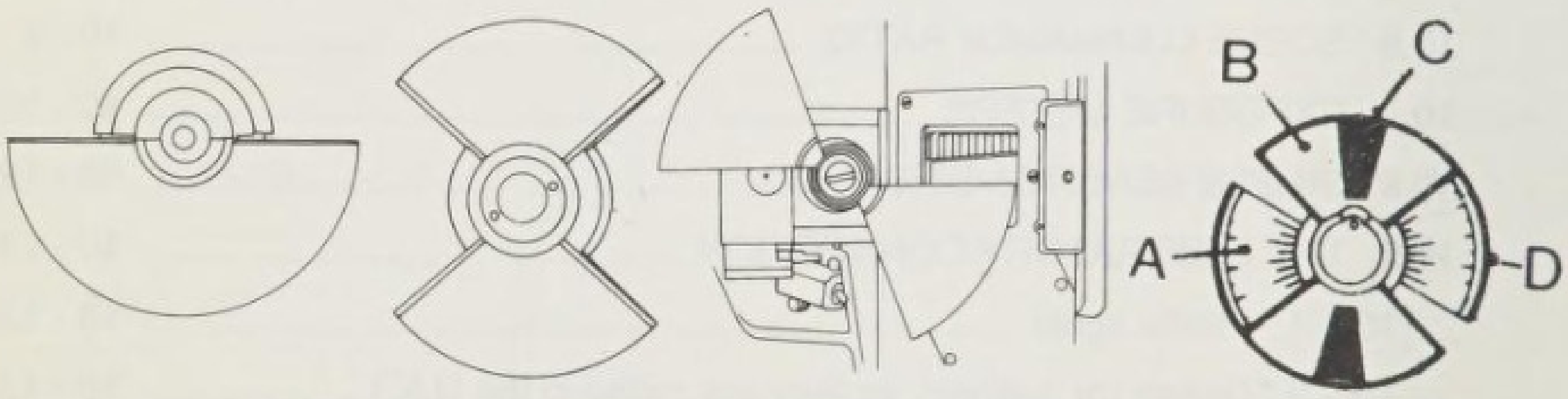
10.1 EXPOSURE TIME

See Section 15.3 for exposure time calculations.

When making exposure calculations the term 'shutter angle' is always taken to apply as though the camera has a shutter with a single blade. Two bladed 'butterfly' shutters, used on many reflex shutter cameras, rotate at half camera speed and have an actual shutter angle opening of only half the rated angle.

Some cameras have a focal plane shutter with a single blade to control the exposure and a separate two bladed spinning mirror used only for reflex viewing purposes.

Some cameras are fitted with shutters which have adjustable openings. Halving any shutter opening halves the exposure time thus decreasing the exposure by one whole stop. Cameras which have a shutter which may be adjusted while the camera is running may be used to make in-shot exposure adjustments.



CAMERA SHUTTER TYPES: 1. Single blade shutter with a 180° opening; 2. Double blade or 'butterfly' type half-speed shutter, also said to have a '180°' opening; 3. Focal plane shutter independent of the rotating reflex mirror (Panaflex), A. Shutter blade, B. Reflex mirror; 4. Combined butterfly type shutter and reflex mirror (Arriflex IICV), A. Adjustable shutter blade (here closed down from 165° full opening to 120° for reduced exposure), B. Reflex mirror, C. Black segment to reduce flicker.

When a camera with an adjustable shutter is in use, the shutter angle should be checked at the commencement of every shooting session to ensure it is as required and has not been reset when the camera was left unattended by the crew responsible.

Cameras with adjustable shutter openings in excess of 180° do not usually also have the facility of closing right down to fully closed or to very small openings.

It is a dangerous practice to close an adjustable shutter down to more than a quarter of its normal aperture without shooting tests beforehand to check that the amount of free floating movement (backlash) between the fixed and the moving shutter blades is not sufficient to cause noticeable irregularity in the exposure of the individual frames which will look like flicker when projected.

The advantages of wide shutter openings are increased exposure, greater blending of individual images with less likelihood of image displacement with the possibility of making faster pan shots and a greater sampling of the overall action.

The advantages of small shutter openings are reduced exposure where wide aperture photography with decreased depth of field is desirable and sharper, better defined images of moving objects but with a sampling rate more widely spaced in time.

In general, Panavision Panaflex 35mm cameras have a maximum shutter opening of 200°, Arriflex 65mm, 535, 35BL's, 16mm SR's, Moviecam and Panaflex 16mm cameras have 180°, Panavision 65mm, PSR's and Mitchell NC's have 175°, Mitchell S35 MkII's have 170°, Arriflex 35IIC's have 165° and Photosonics high speed cameras have 120°.

SHUTTER OPENINGS RELATIVE TO MAXIMUM SHUTTER OPENING
(In 1 stop and 1/3 stop increments)

	SHUTTER OPENING (˚)					
Maximum	**200**	**180**	**175**	**170**	**165**	**120**
Less 1/3 stop	159	1410.33	139	135	131	95
Less 2/3 stop	126	113	110	107	104	76
Less 1 stop	**100**	**90**	**87**	**85**	**82**	**60**
Less 1 1/3 stop	79	71	69	67	65	48
Less 1 2/3 stop	63	57	55	54	52	38
Less 2 stops	**50**	**45**	**44**	**43**	**41**	**30**
Less 2 1/3 stops	40	36	35	34	33	24
Less 2 2/3 stops	31	28	28	27	26	19
Less 3 stops	**25**	**22**	**22**	**21**	**21**	**15**

NOTES:

1. A 200˚ shutter passes 1/6 stop more light than a 180˚ and 1/3 stop more than 165˚.

2. Halving the angle halves the exposure.

3. To make an approximate calculation of a decrease or increase of 1/3 stop divide or multiply any shutter opening by 1.26.

4. Rotating mirror reflex cameras which also incorporate a focal plane light shutter may have a mirror smaller than the maximum shutter angle to allow for the fact that light diverges from the exit pupil of the lens.

10.1.1 Exposure change look-up tables

APERTURE/CAMERA SPEED CORRECTION

If the exposure at 24 fps is known the corrected exposure at other camera speeds may be noted:

FRAMES	EXPOSURE AT 24 FPS										
PER	1	1.4	2	2.8	4	5.6	8	11	16	22	32
SECOND	CORRECTED EXPOSURE										
4	2.4	3.4	4.9	6.9	9.8	14	20	27	39	54	78
6	2	2.8	4	5.6	8	11	16	22	32	44	64
8	1.7	2.4	3.5	4.8	6.9	9.7	14	19	28	38	55
12	1.4	2	2.8	4	5.7	7.9	11	16	23	31	45
16	1.2	1.7	2.4	3.4	4.9	6.9	9.8	13	20	27	39
20	1.1	1.5	2.2	3.1	4.4	6.1	8.8	12	18	24	35
24	**1**	**1.4**	**2**	**2.8**	**4**	**5.6**	**8**	**11**	**16**	**22**	**32**
28		1.3	1.9	2.6	3.7	5.2	7.4	10	15	20	30
32		1.2	1.7	2.4	3.5	4.8	6.9	9.5	14	19	28
36		1.1	1.6	2.3	3.3	4.6	6.5	9	13	18	26
40		1.1	1.5	2.2	3.1	4.3	6.2	8.5	12	17	25
48		1	1.4	2	2.8	4	5.7	7.8	11	16	23
60			1.3	1.8	2.5	3.5	5.1	7	10	14	20
72			1.2	1.6	2.3	3.2	4.6	6.4	9.2	13	18
96			1	1.4	2	2.8	4	5.5	8	11	16
120				1.3	1.8	2.5	3.6	4.9	7.2	9.8	14
240					1.3	1.8	2.5	3.5	5.1	7	10
360					1	1.4	2	2.8	4	5.6	8
500						1.2	1.8	2.4	3.5	4.8	7
1000							1.2	1.7	2.5	3.4	5
2500								1	1.5	2.1	3.1

APERTURE/FILM SPEED CORRECTION

If the exposure at known EI is known the corrected exposure at any other EI rating may be noted:

KNOWN EI	KNOWN EI EXPOSURE										
64	0.8	1.1	1.6	2.2	3.2	4.5	6.4	8.8	12.8	17.6	25.6
100	1	1.4	2	2.8	4	5.6	8	11	16	22	32
125	1.1	1.6	2.2	3.1	4.5	6.3	8.9	12.3	17.9	24.6	35.8
200	1.4	2	2.8	4	5.7	7.9	11.3	15.6	22.6	31.1	45.3
250	1.6	2.2	3.2	4.4	6.3	8.9	12.6	17.4	25.3	34.8	50.6
400	2	2.8	4	5.6	8	11.2	16	22	32	44	64
NEW EI	CORRECTED EXPOSURE AT NEW EI										
1000	3.2	4.4	6.3	8.9	12.6	17.7	25.3	34.8	50.6	69.6	101.2
800	2.8	4	5.7	7.9	11.3	15.8	22.6	31.1	45.3	62.2	90.5
500	2.2	3.1	4.5	6.3	8.9	12.5	17.9	24.6	35.8	49.2	71.6
400	2	2.8	4	5.6	8	11.2	16	22	32	44	64
250	1.6	2.2	3.2	4.4	6.3	8.9	12.6	17.4	25.3	34.8	50.6
200	1.4	2	2.8	4	5.7	7.9	11.3	15.6	22.6	31.1	45.3
125	1.1	1.6	2.2	3.1	4.5	6.3	8.9	12.3	17.9	24.6	35.8
100	1	1.4	2	2.8	4	5.6	8	11	16	22	32
64	0.8	1.1	1.6	2.2	3.2	4.5	6.4	8.8	12.8	17.6	25.6

APERTURE/SHUTTER OPENING CORRECTION

If the exposure with a 180° shutter opening is known the corrected exposure at any other shutter opening may be noted:

SHUTTER OPENING (°)	EXPOSURE AT 180° SHUTTER OPENING										
	1	1.4	2	2.8	4	5.6	8	11	16	22	32
	CORRECTED EXPOSURE										
200	1.1	1.5	2.1	3	4.2	5.9	8.4	12	17	23	34
180	**1**	**1.4**	**2**	**2.8**	**4**	**5.6**	**8**	**11**	**16**	**22**	**32**
172.8	1	1.4	2	2.7	3.9	5.5	7.8	10.8	16	22	31
160		1.3	1.9	2.6	3.8	5.3	7.5	10.4	15	21	30
150		1.3	1.8	2.6	3.7	5.1	7.3	10	15	20	29
144		1.3	1.8	2.5	3.6	5	7.2	9.8	14	20	29
120		1.1	1.6	2.3	3.3	4.6	6.5	9	13	18	26
100		1	1.5	2.1	3	4.2	6	8.2	12	16	24
90		1	1.4	2	2.8	4	5.7	7.8	11	16	23
80			1.3	1.9	2.7	3.7	5.3	7.3	11	15	21
60			1.2	1.6	2.3	3.2	4.6	6.4	9.2	13	18
50			1.1	1.5	2.1	3	4.2	5.8	8.4	12	17
40				1.3	1.9	2.6	3.8	5.2	7.5	10	15
20					1.3	1.9	2.7	3.7	5.3	7.3	11
10						1.3	1.9	2.6	3.8	5.2	7.5

FILM SPEED/LIGHT LEVEL CORRECTION

If the exposure for a particular EI rating and lighting level are known the exposure for any change of film speed or light level can be noted.

LIGHT		EI RATING													
		50	64	80	100	125	160	200	250	320	400	500	640	800	1000
Ft. C	LUX	APERTURE													
5	54								1	1.1	1.3	1.4	1.6	1.8	2
6	65							1	1.1	1.2	1.4	1.5	1.8	2	2.2
8	86						1	1.1	1.3	1.4	1.6	1.8	2	2.3	2.5
10	108					1	1.1	1.3	1.4	1.6	1.8	2	2.3	2.5	2.8
12.5	135				1	1.1	1.3	1.4	1.6	1.8	2	2.2	2.5	2.8	3.2
16	172			1	1.1	1.3	1.4	1.6	1.8	2	2.3	2.5	2.9	3.2	3.6
20	215		1	1.1	1.3	1.4	1.6	1.8	2	2.3	2.5	2.8	3.2	3.6	4
25	269	1	1.1	1.3	1.4	1.6	1.8	2	2.2	2.5	2.8	3.2	3.6	4	4.5
32	345	1.1	1.3	1.4	1.6	1.8	2	2.3	2.5	2.9	3.2	3.6	4	4.5	5.1
40	431	1.3	1.4	1.6	1.8	2	2.3	2.5	2.8	3.2	3.6	4	4.5	5.1	5.7
50	538	1.4	1.6	1.8	2	2.2	2.5	2.8	3.2	3.6	4	4.5	5.1	5.7	6.3
64	689	1.6	1.8	2	2.3	2.5	2.9	3.2	3.6	4	4.5	5.1	5.7	6.4	7.2
80	861	1.8	2	2.3	2.5	2.8	3.2	3.6	4	4.5	5.1	5.7	6.4	7.2	8
100	1077	2	2.3	2.5	2.8	3.2	3.6	4	4.5	5.1	5.7	6.3	7.2	8	8.9
125	1346	2.2	2.5	2.8	3.2	3.5	4	4.5	5	5.7	6.3	7.1	8	8.9	10
160	1723	2.5	2.9	3.2	3.6	4	4.5	5.1	5.7	6.4	7.2	8	9.1	10.1	11.3
200	2153	2.8	3.2	3.6	4	4.5	5.1	5.7	6.3	7.2	8	8.9	10.1	11.3	12.6
250	2692	3.2	3.6	4	4.5	5	5.7	6.3	7.1	8	8.9	10	11.3	12.6	14.1
400	4307	4	4.5	5.1	5.7	6.3	7.2	8	8.9	10.1	11.3	12.6	14.3	16	17.9
500	5383	4.5	5.1	5.7	6.3	7.1	8	8.9	10	11.3	12.6	14.1	16	17.9	20
640	6890	5.1	5.7	6.4	7.2	8	9.1	10.1	11.3	12.8	14.3	16	18.1	20.2	22.6
800	8613	5.7	6.4	7.2	8	8.9	10.1	11.3	12.6	14.3	16	17.9	20.2	22.6	25.3
1000	10766	6.3	7.2	8	8.9	10	11.3	12.6	14.1	16	17.9	20	22.6	25.3	28.3

10.2 FILM SPEED

There is no official standard for motion picture color negative film speed measurement. Manufacturers rate emulsion sensitivity in Exposure Index (EI) units taking into consideration the spectral quality of the light in which it is intended to be used, the likely exposure duration, the recommended development process, the density and contrast most likely to be desired, the degree of acceptable granularity and the latitude of the emulsion.

EI units are sometimes erroneously referred to as 'ASA numbers', named after the old American Standards Association, now the American National Standards Institute (ANSI). ASA ratings are intended for stills usage and are not exactly the same as EI units which are more suitable for cine use.

Doubling an EI number doubles the film speed, EI 200 film being twice as sensitive as EI 100, and are quoted in 1/3 stop increments, i.e. 64, 80, 100, 125, 160, 200 etc.

Another frequently used method of referring to filmstock sensitivity is the German DIN (Deutsche Industrie Norm) rating. DIN ratings proceed in multiples of three, increasing the DIN number by 3 indicates the speed of the film is doubled. An increase of one indicates a 1/3 stop difference. 21 DIN is equal to EI 100, 24 DIN to EI 200, 27 DIN to EI 400 and so on.

As an additional guide to the sensitivity of a particular film stock, manufacturers also recommend the intensity of the key light they consider necessary to illuminate an average subject for a given T stop, i.e. Kodak recommends that 200 foot candles or 2150 Lux is necessary for an exposure of T4 using their EI 125 filmstock.

EI, ASA, DIN or F. or lux for a given exposure are all only intended as a guide. Cameramen should make their own tests with their own meters using the particular type or types of filmstock, the particular filters. It should then be processed at the laboratory to be used during the production and have it printed on a preferred print stock to produce a positive image which upon projection has the particular look about it that they wish to achieve and a graininess which they find acceptable.

There are many factors which contribute to the rating that a cameraman will give to a particular filmstock on a particular production, not least of which is the desirable look to interpret a particular script and for this the stock manufacturer's rating should be taken only as a starting point for tests or the basis for experience.

10.3 RECIPROCITY FACTORS

If exposures in excess of 1 sec or shorter than 1/1000 sec are required, a phenomenon known as 'Reciprocity Failure' becomes a factor. Film emulsions are designed to react best to light over a certain period of exposure. If that time is exceeded or reduced, proportionately more exposure and perhaps a color correction filter may be required to compensate. The compensation required varies greatly between different types of film stock and either the manufacturer should be contacted or tests should be made.

10.4 SUBJECT FACTORS

When selecting the exposure to be given for a particular scene, the light and shade and reflectance characteristics of the scene itself must be taken into consideration.

Although at first glance we may look at a subject in terms of color the emulsion of a film, even color film, is only sensitive to monochromatic light and shade and looks at it in terms of how much 'gray' light is reflected off the particular elements of the subject. Film becomes 'color' film by filtering color into three separate layers of gray, representing the red, green and blue components of light respectively.

Each part of the surface of any scene will reflect a certain proportion but not all of the overall white light falling on it. The reflected light can, therefore, be said to be gray.

The brightest white object, such as a white wall or shirt, in an interior scene will reflect about 81% of the light falling on it, the deepest black (black velvet, etc.) about 4%.

The 'average' amount of gray light being reflected from a subject may be calculated as the 'square root of the product of the highest and lowest percentages of reflected light' viz: $\sqrt{81} \times 4$ = 18%. A gray card with an 18% reflectance is often used as a reference when taking reflected light reading of interior subjects.

Incident light exposure meters are manufactured and calibrated to the same premise that the average interior subject will reflect 18% of the light falling upon it.

White, Caucasian faces reflect an average of about 20 – 25% of the light falling on them.

There is, of course, no such thing as an 'average' skin tone but as human faces are very often the most important component of a scene a cameraman must then take the reflectivity of the most important face in a scene, particularly when shooting close-ups, into consideration to ensure that the photographic exposure places the skin tones in the center of the sensitivity range of the filmstock. A reflected light spot meter is a very efficient means of reading the amount of light being reflected off a particular face when it is desirable to give flesh tones exposure priority.

The average amount of light reflected by an 'exterior' subject is usually less than that of an interior, and may be as low as 12% due to atmospheric conditions which scatter the light from the sun and from the subject. For this reason it may be desirable, if using a standard 18% gray scale reference card or taking an incident light reading of a wide angle exterior scene, to increase the exposure by 1/3 or even 2/3 of a stop to compensate. Other exterior factors, from night-for-night to sunlit snow, must also be allowed for.

The nature of the subject may well affect the color of the photographic image. Blue flowers, for instance, often contain a great deal of infra-red which is not seen by the human eye but when photographed make them look purplish. Many fluorescent lamps give out a spectrum of light which has a very narrow, but intense, green 'spike' which is not noticeable to humans but which does photograph, making such lights look greenish when seen in direct comparison with daylight or tungsten light. Modern filmstocks often incorporate a special narrow band filter to counter this spike.

Although it is most important to consider how much 'gray' light is reflected off a subject, the combination of color and texture of a subject must also be considered. Pastel colors, such as yellow and beige, for instance, reflect more light than saturated colors such as maroon, purple and dark blue. A surface which is glossy or shiny will reflect more light than one with a deep rough texture, a curved surface more than a flat one, a flat one reflecting light from a single source towards the camera more than a similar surface reflecting the light away, and so on.

At this point the nature of the lighting itself must also be taken into consideration because a bright light from a single source, be it a fresnel lamp or the sun, will produce a greater reflectance off a shiny brightly colored surface than an overall diffused light being bounced off a white board or from a gray sky.

A cameraman must mentally take all these factors into consideration if he wishes to make full use of the entire exposure range of the filmstock.

LIGHT REFLECTIVITY OF COLORS

COLOR	REFLECTIVITY
Red (bright red)	15 – 21
Orange	35 – 45
Yellow (dark yellow)	65 – 75
Green (dark leaf-green)	18 – 26
Blue	15 – 21
Indigo	6 – 12
Purple	6 – 12

10.5 LIGHTING CONTRAST RATIO

Whenever the principal source of illumination of a scene is from a single source or direction this brightest light source is referred to as the 'key' light and any light used to lighten the shadows, the 'fill' light.

The relative brightness of the key light plus the fill light compared to the fill light alone is the 'lighting contrast ratio'. In the case of day exteriors the sun provides the key light and reflected or refracted light from the sky, or by artificial means, provides the fill.

Over the years lighting contrast ratios used in color cinematography under controlled conditions have been reduced and reduced until a lighting style which is virtually shadowless has become quite acceptable, the photographic separation in the elements of a scene being by color rather than contrast.

There are no rules to be obeyed, cinematographers must decide upon the look they desire and set their lights and reflectors, etc. accordingly. Suffice to say that a ratio of 4:1 is quite contrasty for color, 1.5 or 2:1 is good for television transmission and totally flat light bounced off large white surfaces or passed through large white diffusers or screens is acceptable providing the subject has sufficient inherent color contrast and the materials are of average reflectance.

When setting lights and wishing to keep to a constant lighting contrast ratio it is important to remember that the 'key' light is the combination of all the lighting (principal and fill light) and that the key light reading should be taken with all lights on. This is because a certain amount of light from the fill light (which is usually placed closest to the camera) will illuminate the brightest area of the scene in addition to the brightest light source and the two must be measured together and compared with that of the fill light *only* to determine the lighting contrast ratio. Failure to observe this fact can result in an incorrect assessment of the ratio. Alternatively, when seeking to illuminate a scene to a given lighting level of, say 400 fc to shoot at T5.6 cameramen may set the principal light at a slightly less intensity than that required for the key light so that when the fill light is added the overall lighting level will be as required.

As already stated, there are no rules. Occasions when the brightest source of light is from, say, three quarter behind or more, or where special lighting effects are desirable, must each be taken on their own merits.

When shooting exteriors, where the natural lighting contrast from a bright sun may be as high as 250:1 (7 or 8 stops), or more, it may be necessary to control the lighting contrast of the most important elements of the scene. This may either be done by using powerful light sources to fill the shadows or using a scrim (net) or other large sheet of material to shade off the sunlight falling on the principal area and lighting this separately by artificial light.

Daylight fill is particularly important when strong sunlight comes from a high angle or from the side or behind, causing undesirable face shadows, particularly about the eyes and the chins of artists. Nothing looks worse than black sockets where eyes should be, unless that is a desired look.

LIGHTING CONTRAST RATIO TABLE

To check the lighting contrast or to set it to a predetermined level, measure the combined light level of the key light and fill light together (using a flat type photodisk) and compare it with the reading for fill light alone (using a domed type photosphere).

This table indicates the approximate lighting contrast ratios. It may be used for foot candles or lux light readings.

KEY LIGHT AND FILL LIGHT COMBINED	APPROXIMATE CONTRAST RATIO							
	1.5:1	2:1	2.5:1	3:1	4:1	5:1	6:1	8:1
	FILL LIGHT ALONE							
1.6	1.25	1						
2	1.6	1.25	1					
2.5	2	1.6	1.25	1				
3.2	2.5	2	1.6	1.25	1			
4	3.2	2.5	2	1.6	1.25	1		
5	4	3.2	2.5	2	1.6	1.25	1	
6.4	5	4	3.2	2.5	2	1.6	1.25	1
8	6.4	5	4	3.2	2.5	2	1.6	1.25
10	8	6.4	5	4	3.2	2.5	2	1.6
12.5	10	8	6.4	5	4	3.2	2.5	2
16	12.5	10	8	6.4	5	4	3.2	2.5
20	16	12.5	10	8	6.4	5	4	3.2
25	20	16	12.5	10	8	6.4	5	4
32	25	20	16	12.5	10	8	6.4	5
40	32	25	20	16	12.5	10	8	6.4
50	40	32	25	20	16	12.5	10	8
64	50	40	32	25	20	16	12.5	10
80	64	50	40	32	25	20	16	12.5
100	80	64	50	40	32	25	20	16
125	100	80	64	50	40	32	25	20
160	125	100	80	64	50	40	32	25
200	160	125	100	80	64	50	40	32
250	200	160	125	100	80	64	50	40
320	250	200	160	125	100	80	64	50
400	320	250	200	160	125	100	80	64
500	400	320	250	200	160	125	100	80
640	500	400	320	250	200	160	125	100
800	640	500	400	320	250	200	160	125
1000	800	640	500	400	320	250	200	160
1250	1000	800	640	500	400	320	250	200
1600	1250	1000	800	640	500	400	320	250
2000	1600	1250	1000	800	640	500	400	320
2500	2000	1600	1250	1000	800	640	500	400
3200	2500	2000	1600	1250	1000	800	640	500

10.6 SCENE LUMINANCE RATIO

The shades of light which produce the photographic exposure in the camera is subject to the reflectance ranges of the subject and the lighting ratio. Between these two factors a subject can be very contrasty, having some areas which are reflecting a great deal of light, such as whitewashed walls in full sunlight, and very dark, unlit areas of shade with few mid tones, while other scenes may have only tones of a similar luminance, be they light, dark or mid-range, and are said to look 'flat'. The 'flatness' and 'brightness' of scene contrast are human judgements of the luminance range and part of where the art comes into cinematography. The luminance range may be measured by reflected light meters, particularly spot meters which, with their very narrow angles of acceptance, can be used selectively to measure significant light and dark areas of a scene.

The amount of light that a film projector can transmit is limited to that of the clearest area of the film emulsion and the density of the film base, for even a clear area will always hold back something. Similarly, a true black is impossible to achieve as some light always leaks through even the densest area of the film. It is said that a well-exposed and processed color negative can record a maximum luminance range of 200:1 and that to keep within a range of 125:1 (seven stops) will ensure that texture detail will show in the whitest whites and in the blackest blacks.

Color reversal film has a much lower exposure latitude (1/2 stop either way, usually) and cameramen should limit their range to 64:1 if they wish to ensure satisfactory prints with full detail subsequently.

When shooting interiors, where the luminance range can be controlled, it is not difficult to keep within the recommended luminance ratio range but on exteriors, where the ratio can go beyond 500:1, it can be very difficult and sometimes impossible.

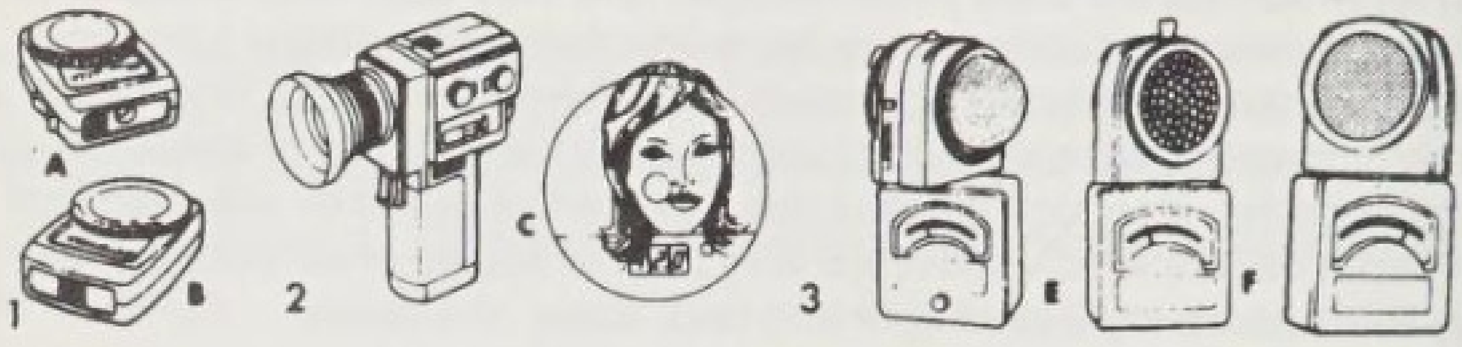
The use of fill light, of large nets or scrims to keep the direct sunlight off principal artists, the use of low contrast filter or of shooting with the sun less to the side of a scene and more behind the camera, are all means of reducing excessive contrast on exteriors.

SCENE LUMINANCE RATIO TABLE

STOPS DIFFERENCE BETWEEN LIGHTEST AND DARKEST AREAS OF A SCENE	SCENE LUMINANCE RATIO
5	32:1
5 1/3	40:1
5 2/3	50:1
6	64:1 Safe max for color reversal
6 1/3	80:1
6 2/3	100:1 Safe max for color negative keeping all information on the straight line portion of the sensitometric curve
7	125:1
7 1/3	160:1
7 2/3	200:1 Max color negative can resolve with some information in the toe and the shoulder of the curve
8	250:1
8 1/3	320:1
8 2/3	400:1
9	500:1
9 1/3	640:1
9 2/3	800:1
10	1000:1

10.7 EXPOSURE METERS

Cameramen use a selection of exposure meters for different purposes depending upon the conditions, the scene, the lens and the control required.



TYPICAL EXPOSURE METERS: 1. General purpose meter which may be used for both A. Reflected and B. Incident light measurement; 2. Spot meter, C. Image seen through the meter, a small circle indicates the area where light is being measured; 3. Spectra meter D. Fitted with a domed Photosphere to measure incident light, E. A lenticular Photogrid to measure reflected light and F. A flat Photodisk to measure light from a single source.

For photographic purposes light falling on a subject (incident light) is measured in foot candles or lux by a meter held near the subject and directed towards the camera. Incident light meters have a hemispherical dome made of a translucent material set in front of the photo-electric cell to collect a sample of all useful light from all directions falling on the subject.

Some incident light meters also have an alternative flat translucent disk which may be used to measure the light from a single source. This accessory is particularly used by cameramen and gaffers wishing to measure the intensity of a particular light source and is not usually used for exposure evaluation.

Light reflected off a subject is measured in foot lamberts or candelas by a meter pointed at either the whole of the principal area of a scene or a sample area of average reflectance. (Screen brightness is also measured in foot lamberts or candelas and an ordinary reflected light meter may also be used for this purpose.)

General purpose reflected light meters usually take in a cone of light of about 30 degrees conforming to something less than an average camera lens angle. Accessories are often available to cover a reduced angle of 15 or 7.5 degrees, to make a more selected evaluation, especially when using the long end of a zoom or a telephoto lens.

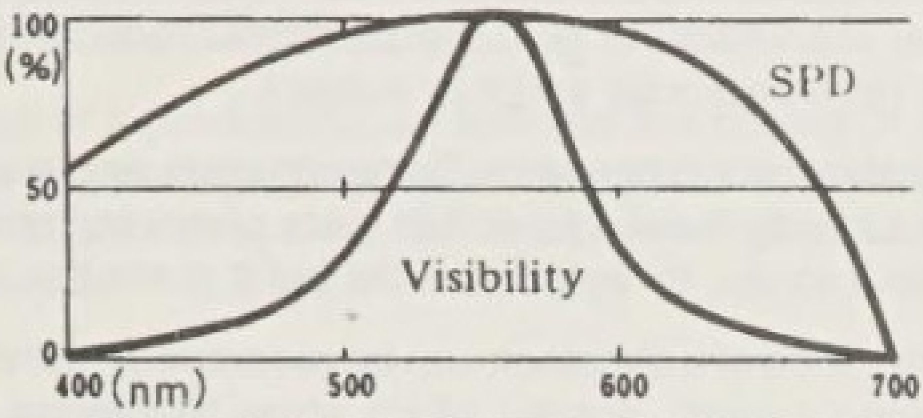
Spot meters, be they analog or digital, are reflected light meters with a very narrow angle of acceptance (1 degree or less) and are used to sample the light reflected off a selected area without the necessity of going very close to that area with a regular reflected light meter. They are particularly used by feature film cameramen to take readings off the most important flesh tones in a scene to ensure they print in the center of the scale, and by documentary cameramen who do not wish to disturb a subject by poking a regular exposure meter in their face at close quarters.

Other types of reflected light meter attachments available are a fiber optic probe accessory which permits light readings off small areas of a focusing screen and an adaptor for use when shooting through a microscope.

Certain 16mm and Super 8 cameras incorporate integral 'through the lens' light meters which sample the light reflected off a selected area of the scene. Care should be taken when using such a meter to ensure that any reading is not incorrectly influenced by any particularly bright (sky) or dark (wooded) area which could give a far from average exposure setting. With such a facility it is usually best to take a reading with the meter of an average brightness area of the picture (Caucasian skin tones are ideal) with the zoom lens, if fitted, set to maximum focal length, and fix the exposure at that for the entire scene. An automatic exposure meter adjusting itself throughout a scene as the camera is panned from an area of light background to a dark one is rarely a good thing.

In addition to differing in the manner in which they collect light, exposure meters also vary in the way in which they are read. Analogue type meter have a needle which points to a scale while digital meters show a precise exposure number, usually to 1/10 stop, much finer than lenses can be scaled to or that matters in the real world. Laboratory type meters are usually calibrated to read only foot candles or lux for incidence light and foot lamberts or candelas per square meter (nits) for reflected light. Photographic meters either read directly in 'T stops' for a pre-set exposure time and film speed, read off an arbitrary scale which is then translated into a meaningful exposure by adjusting of a series of rotatable circular disks or may be set to a norm and will read a plus or minus exposure to that norm.

Exposure meters are not suitable for measuring the brightness of travelling matte screens as they have a sensitivity level at either end of the spectrum of visible light which is far greater than the sensitivity of film.



SILICON PHOTO DIODE SENSITIVITY

Photographic incident light meters, especially spot meters, can also be used to measure screen luminance. The ANSI standard for screen luminance for normal review room and primary theaters is 16±2 fL, 55±7 cd/m$_2$. In other countries it is often somewhat less. Measurements should be taken with the projector running at 24 fps, with no film in the gate and with the lens correctly focused.

If the meter is not calibrated to read foot lamberts or candelas per square meter it is possible to calculate the luminance using the table below.

GOSSEN EXPOSURE METER CONVERSION TABLE

Film speed/Exposure value/Foot Lamberts/ Candelas per sq. Meter/Lux/Foot Candles.

Gossen exposure meters, like many other exposure meters, give readings in Exposure Values according to the filmspeed settings. A dial on the meter is then used to translate the EV into an exposure setting with regard to the exposure time and lens aperture. The following table shows how these readings may be converted to foot lamberts or candelas per square meter in the case of reflected light or foot candles and lux in the case of incident light. The table conforms to DIN Standard 19010 and is supplied by Gossen GmbH.

Reflected Light		Incident Light		Exposure Values					
Candelas per sq. meter	Foot lamberts	Lux	Foot candles	Film Speed					
				Din EI	18 50	21 100	24 200	27 400	30 800
0.22	0.064	5.5	0.5		0	1	2	3	4
0.44	0.125	11	1		1	2	3	4	5
0.68	0.25	22	2		2	3	4	5	6
1.75	0.5	44	4		3	4	5	6	7
3.5	1	88	8		4	5	6	7	8
7	2	175	16		5	6	7	8	9
14	4	350	32		6	7	8	9	10
28	8	700	64		7	8	9	10	11
55	16	1400	125		8	9	10	11	12
110	32	2800	250		9	10	11	12	13
220	64	5500	500		10	11	12	13	14
440	125	11000	1000		11	12	13	14	15
880	250	22000	2000		12	13	14	15	16
1750	500	44000	4000		13	14	15	16	17
3500	1000	88000	8000		14	15	16	17	18
7000	2000	175000	16000		15	16	17	18	19
14000	4000	350000	32000		16	17	18	19	20

1 fl = 3.426 cd/m^2
1 cd/m^2 = 0.292 fl

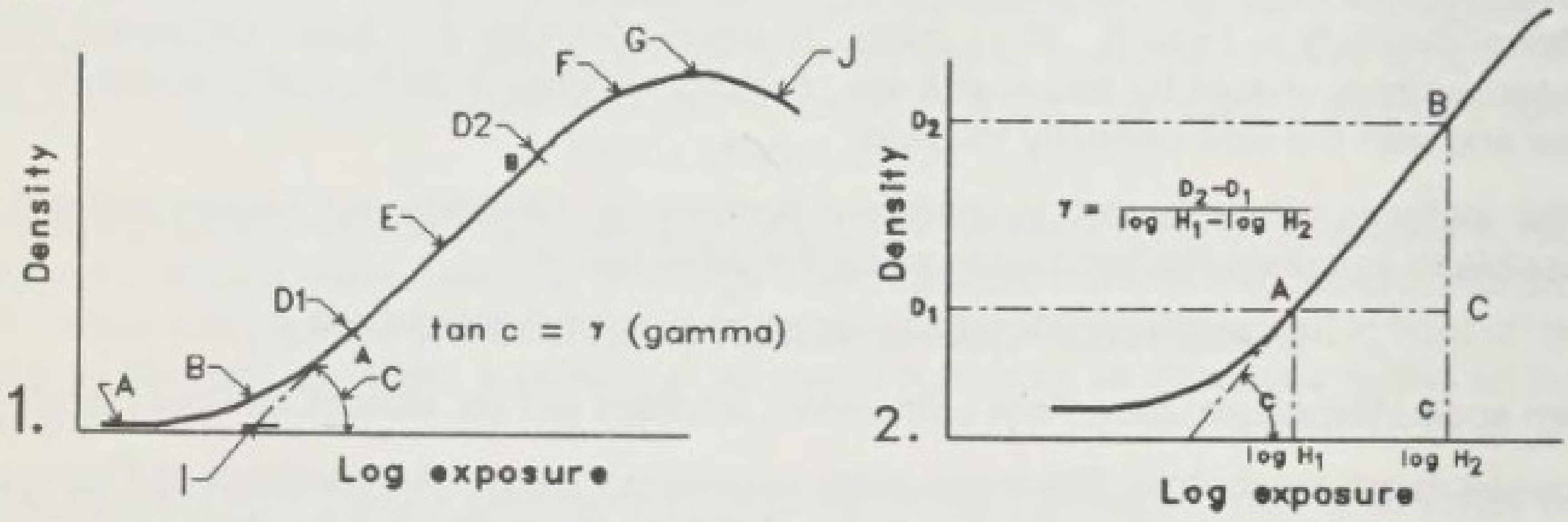
1 fc = 10.76 lux
1 lux = 0.093 fc

10.8 SIMPLE SENSITOMETRY

Cinematographers select which filmstock or series of filmstocks to use on a particular production for a number of reasons. Ideally these reasons are that a the series of filmstocks produced by a particular manufacturer give the particular 'look' or 'feeling' to an image that is required to interpret a particular script or subject.

The words 'look' and 'feeling' encompass many parameters and each experienced cinematographer will undoubtedly have his or her own particular reasons. Tonal reproduction, especially of flesh tones, is high on the list but it is not the only parameter.

The photographic performance of a filmstock can be measured, monitored and visualized by so-called 'sensitometric curves', graphs which show the image density against the amount of exposure to light. For color film a sensitometric curve is produced for each color layer but for reference purposes it is usually sufficient to refer only to the green curve.



SENSITOMETRIC CURVES: 1. The 'geography' of a sensitometric curve:A. Threshold (base + fog) or 'D_{min}'; B. Toe region; C. The angle which is the 'gamma' or measure of contrast; D_1. Bottom of the straight line portion; E. Linear or 'straight line' region; D_2 Top of straight line portion; F. Shoulder region; G. Maximum density (D_{max}); I. Inertia point; J. Region of solarization (reversal); 2. GAMMA IN TERMS OF DENSITY AND LOG EXPOSURE: Gamma = tan c.

The contrast of a film is measured by plotting the angle of the straight-line portion of the curve to the base line. 'Gamma', the measure of image contrast is the tan of that angle ($\tan C = \gamma(\text{gamma})$). If the angle of the straight-line portion were to be 45° the gamma would be 1. The steeper the curve the higher the gamma and the higher the contrast. In a laboratory sensitometric curves are used to monitor film processing, there being a film-stock manufacturer's norm and tolerances which set and keep the standards. Frequently a lab will put a pre-exposed test strip through the processing bath and plot the results.

Extended development will increase the contrast, the image density and, incidentally, the graininess of an image.

For optimum image reproduction the brightness-range of an image should photograph only on the straight-line portion of the curve and for most color negative material this is a subject brightness range of 100:1. Any movement from the center will result either in less shadow detail or in burnt-out highlights.

A subject with a lesser brightness range, say 10:1, can be moved up and down the straight-line portion without any deleterious effect and the film might be thought to have greater exposure latitude.

A subject with greater brightness range, say 125:1, would result in the image extending into the toe or the shoulder areas of the curve where the reproducible detail is lessened.

Color films are balanced to have their three color layers evenly exposed either to daylight, with the blues being stronger than the reds, or to tungsten light where the reds are the stronger. Where exposures are made outside of the intended color temperature norm Color Correction filters, such as an 85B or an 80A, are used to redress the balance. If a needed filter is not used the result will mean the imbalance of exposure between the layers and the loss of detail in the shadow and/or highlight areas of complementary colors, but not others. i.e., if an 85B filter is not used when using film balanced for tungsten light to film by daylight, and the subject is correctly exposed and spans the full 100:1 subject brightness-range, there will be less detail and density in the blue shadows than in the other colors and therefore the shadows will look warmer. If the subject range were only 10:1 and the exposure is in the center of the curve there would be little difference.

It is all part of the way experienced Directors of Photography manipulate the look of their images and why it is necessary to work closely with the laboratory.

10.9 THE LABORATORY CONNECTION

Throughout the production one of the cinematographer's closest associates will be the Laboratory Contact person. Between the two there should be daily contact and a steady flow of useful information in both directions.

From the very outset of a production, as soon as the choice of a processing laboratory has been made, the cinematographer will outline to the contact person the overall 'look' and sort of mood or effect that is to be achieved and where on the printer scale the ideal exposure level should lie.

10.9.1 Printer lights

Most laboratories use a 51 point printer scale with printer lights of 25-25-25 for the red, green and blue layers being 'center of the scale'. However, the cinematographer may well opt for, say, 30-30-30 to be the desired norm in order to give a little more exposure in the shadow areas. There may also be slight variations due to differences between the various stock manufacturers and between particular batches of filmstock.

One stop variation in exposure is the equivalent of approximately 12 printer points.

10.9.2 Dailies (or 'rushes', as they are called in the UK)

Major laboratories will process negative and make a 'dailies' print overnight so that it can be examined there and then and a report on the previous day's work sent to the cinematographer by telephone or fax before shooting commences the following morning, or as soon as possible thereafter.

Wherever and whenever circumstances permit, a print of the previous day's work will be delivered to the studio or location for viewing later in the day when the endeavors of the cinematographer will be there on the screen for all to see.

Dailies may either be 'one light' prints (favored in the U.S.A.) or 'timed' (more favored in the U.K.). The advantages of having 'one light' dailies is that they are quicker, cheaper and any variations from the norm (or problems) are there for all to see and for action to be taken. With the latter system the dailies look more like the way the final film will look and any information regarding problems is confined to those who need to know. Timed dailies are also to be preferred if the film's financing is not yet complete and the unfinished work must be shown to an untechnical audience of prospective investors.

10.9.3 Timing the answer print

When the final scene has been photographed, the optical and special effects shots have been incorporated, the picture has been edited, the sound has been dubbed and the production is finally complete, the optimal print, 'the answer print', must be made. The timing of this print, which will be used as an example to which all subsequent prints must compare, is the cinematographer's final contribution to the project.

After the answer print has been approved a master interpositive will be made, using the same printer light settings as the answer print. From this print one or more 'one light' internegatives will be made and from these will come the final 'one light' show prints.

Usually the Editor, who will have been working with the Director and cooperating with the laboratory throughout the production, and who knows the project most intimately, will sit in with the timer and the cinematographer during this process. The Director may also wish to have a final say at this time. Timing by committee, with all the various layers of Producers and even a representative of the distribution company, all having their say, is to be avoided.

10.9.4 Video release print

For television release, the only different requirement is that a special print for telecine use should be made using low-contrast print filmstock. Otherwise, anything (other than aspect ratio incompatibility) that is good for showing by projection can be accommodated by modern telecine transfer technology.

Aspect ratio incompatibility is another problem and if the motion picture has been shot to take full advantage of the wide screen, particularly if it is in the anamorphic 2.35:1 ratio, then it is also a good idea for the Director of Photography to sit in on the telecine transfer session to supervise the panning and scanning process.

11 FILMSTOCK

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The following are listings of the motion picture camera and laboratory filmstocks currently marketed by the three leading manufacturers.

The types of filmstock available from the manufacturers and their specifications are constantly changing. It seems that almost every month or so, one or other of the manufacturers introduces a new emulsion and/or discontinues an old one. This makes it very difficult for a manual such as this to keep up-to-date.

While the data listed below was current at the time of going to press there is no saying if that will be so the day following. When in doubt it is better to telephone or fax the manufacturers for the very latest information. See Section 1.2 for a listing of telephone and fax numbers.

11.1 35mm CAMERA FILMS - COLOR NEGATIVE

AGFA 35mm color negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
XT 100	Tungsten	64 (+85)	100	200	2150	N
XT 320	Tungsten	200 (+85)	320	64	675	F
XTS 400	Tungsten	250 (+85)	400	50	540	S

EASTMAN KODAK 35mm color negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
EXR 50D 5245	Daylight	50	12 (+80A)	400	4300	K
EXR 100T 5248	Tungsten	64 (+85)	100	200	2150	5248
EXR 200T 5293	Tungsten	125 (85)	200	100	1080	L
EXR 500T 5298	Tungsten	320 (85)	500	40	430	J
5297	Daylight	250	64 (+80A)	80	860	

FUJI 35mm color negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
F-64 8510	Tungsten	40 (+85)	64	320	3460	N10
F-64D 8520	Daylight	64	16 (+80A)	320	3460	N20
F-125 8530	Tungsten	80 (+85)	125	160	1730	N30
F-250 8550	Tungsten	160 (+85)	250	80	860	N50
F-250D 8560	Daylight	250	64 (+80A)	80	860	N60
F-500 8570	Tungsten	320 (+85)	500	40	430	FN70

11.2 16mm CAMERA FILMS - COLOR NEGATIVE

AGFA 16mm color negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
XT 100	Tungsten	64 (+85)	100	200	2150	N
XT 320	Tungsten	200 (+85)	320	64	675	F
XTS 400	Tungsten	250 (+85)	400	50	540	S

EASTMAN KODAK 16mm color negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
EXR 50D 7245	Daylight	50	12 (+80A)	400	4320	K
EXR 100T 7248	Tungsten	64 (+85B)	100	200	2160	7248
EXR 200T 7293	Tungsten	125 (85)	200	100	1080	L
EXR 500T 7298	Tungsten	320 (85)	500	40	430	J
7297	Daylight	250	64 (+80A)	80	860	

FUJI 16mm color negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
F-64 8610	Tungsten	40 (+85)	64	320	3460	N10
F-64D 8620	Daylight	64	16 (+80A)	320	3460	N20
F-125 8630	Tungsten	80 (+85)	125	160	1730	N30
F-250 8620	Tungsten	160 (+85)	250	80	860	N50
F-250D 8660	Daylight	250	64 (+80A)	80	860	N60
F-500 8570	Tungsten	320 (+85)	500	40	430	FN70

11.3 16mm CAMERA FILMS – COLOR REVERSAL

EASTMAN KODAK 16mm color reversal

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
EKTACHROME 7239	Daylight	160	40 (+80A)	125	1350	
EKTACHROME 7240	Tungsten	125	80 (+85B)	160	1722	
EKTACHROME 7250	Tungsten	100 (+80A)	400	50	538	
EKTACHROME 7251	Daylight	400	100 (+80A)	50	538	

FUJI 16mm color reversal

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
RT125 Type 8427	Tungsten	80	125	160	1722	
RT500 Type 8428	Daylight	80	125	160	1722	

11.4 35mm CAMERA FILMS – B&W NEGATIVE

AGFA 35mm b&w negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
PAN 250	n/a	250	200	100	1080	H

EASTMAN KODAK 35mm b&w negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
PLUS-X 5231	n/a	80	64	320	3456	
Double-X 5222	n/a	250	200	100	1080	

ILFORD 35mm b&w negative

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
PAN F Plus	n/a	25-50	20-40	500	5400	
FP4 Plus	n/a	80-160	64-125	160	1730	
HP5 Plus	n/a	250-500	200-400	50	540	

11.5 16mm CAMERA FILMS – B&W

AGFA 16mm b&w

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
PAN 250	n/a	250	200	100	1080	H

EASTMAN KODAK 16mm b&w

Emulsion type	Color balance	Filmspeed rating (EI)		Light required for a f/4 exposure		Ident' letter
		Daylight	Tungsten	f/c	Lux	
Kodak PLUS-X Negative 7231	n/a	80	64	320	3456	
Kodak DOUBLE-X Negative 7222	n/a	250	200	100	1080	
Kodak PLUS-X Reversal 7276	n/a	50	40	500	5400	
Kodak TRI-X Reversal 7278	n/a	200	160	125	1350	
Kodak 4-X Reversal 7277	n/a	400	320	64	670	

ILFORD 16mm b&w negative

As 35mm

11.6 35 & 16mm LABORATORY FILMS – COLOR

AGFA

CP1 Color Positive film	35 & 16mm, Triacetate
CP10 Color Positive film	35 & 16mm, Polyester
782 Gevachrome Print	Color reversal film, 35 & 16mm

EASTMAN KODAK

Color Intermediate II Film 2244/5244/7244 (2244 is a 35/65mm ESTAR base film)	Used for making color master positives from original negatives and duplicate negatives from master positives. A duplicate can be identified on 35mm film by the letter 'D' on the left of the latent-image edge number and on 16mm by the words 'Kodak Safety EC1 Film'.
Color Print Film 5386/7386	Used for making color release prints.
Low Contrast Color Print Film 5385/7385	Used for making prints for T.V.
Eastman Sound Recording Negative Film 5373/7373	Also SO-213 for Estar base.

FUJI

Fujicolor Intermediate Film 8213/8223/8501/8601	Used for making color master positives from original negatives and duplicate negatives from master positives. ECN-2 processing.
Fuji Positive Film LP 8816/8826	ECP-2A or ECP-2B processing.

11.7 35 & 16mm LABORATORY FILMS – B&W

AGFA

464 Duplicating negative-Panchromatic,	16 & 35mm, Polyester
362 Duplicating positive	16 & 35mm, Polyester
553 Positive Super Contrast	16 & 35mm, Polyester
561 Fine grain print film	16 & 35mm, Polyester & Triacetate
ST8 Optical Sound recording Negative	16 & 35mm, Polyester & Triacetate
ST8.D Optical Sound recording Negative	35mm, Polyester

EASTMAN KODAK

Eastman High Contrast Panchromatic 5369	Intermediate b&w film used in the production of optical printer effects such as silhouette and travelling mattes
Panchromatic Separation Film 5235	Used for making b&w separation positives from color negative originals. The best means of long-time archival storage.
Fine Grain Duplicating Panchromatic negative 5234	Used for making duplicate b&w negatives from master positives or internegatives from reversal originals.
Fine Grain Duplicating Positive Film 5366	Blue sensitive b&w film used for making master positives from camera negative originals.
High Contrast Positive Film 5362	Used for making b&w titles and for optical printer matte work.
Direct MP film 5360 & 7360	Used for making b&w work prints.
Fine Grain Release Positive 5302 & 7302	Used for b&w release prints from b&w negatives, etc.

11.8 COLOR CONVERSION FILTERS

Manufacturers recommend the following color conversion filters:

Color conversion filters for color negative filmstock

Light source	FILMSTOCK TYPE			
	DAYLIGHT BALANCED COLOR NEGATIVE		TUNGSTEN BALANCED COLOR NEGATIVE	
	WRATTEN filter	Exposure compensation	WRATTEN filter	Exposure compensation
Tungsten (3000K)	80A	+2 stops	82B	+2/3 stop
Tungsten (3200K)	80A	+2 stops	None	
Tungsten (3400K) (Photoflood)	80A	+2 stops	None	
Daylight (5500K)	None		85	+2/3 stop
Metal Halide	None		85	+2/3 stop
Yellow-Flame Arc	80C	+1 1/3 stops	81C	+1/3 stop
White-Flame Arc	CC20Y + CC10C	+2/3 stop	CC40R + CC50Y	+1 1/3 stops
Optima 32	80A	+2 stops	None	
Vitalite	None		85	+2/3 stop
Fluorescent	Use CC20M for an initial test	+1 1/3 stops	Use CC40R for an initial test	+2/3 stop

Color conversion filters for color reversal filmstock

Light source	FILMSTOCK TYPE			
	DAYLIGHT BALANCED COLOR REVERSAL		TUNGSTEN BALANCED COLOR REVERSAL	
	WRATTEN filter	Exposure compensation	WRATTEN filter	Exposure compensation
Tungsten (3000K)	80A	+2 stops	82B	+2/3 stop
Tungsten (3200K)	80A	+2 stops	None	
Tungsten (3400K) (Photoflood)	80B	+1 2/3 stops	81A	+1/3 stop
Daylight (5500K)	None		85B	+2/3 stop
Metal Halide	None		85B	+2/3 stop
Yellow-Flame Arc	80A	+2 stops	None	+
White-Flame Arc	None		85B	+2/3 stops
Optima 32	80A	+2 stops	None	
Vitalite	None		85B	+2/3 stop
Fluorescent	Use CC20M for an initial test	+2/3 stops	Use CC40R for an initial test	+1 stop

The above data is published by Eastman Kodak but is equally applicable to color filmstocks supplied by other manufacturers.

11.9 NOTES ON THE STRUCTURE OF COLOR FILM

Color film is made up of a multitude of layers which go to make the highly sophisticated filmstocks that we use every day and take very much for granted. These superimposed layers comprise photo-sensitive emulsions, dye coloring chemicals, color filters, anti-reflection barriers and the film base itself. On the top of it all is an anti-abrasion layer to protect all the other layers from becoming damaged and behind it all is a black resin backing layer which guards against abrasion and scratching as the film passes through the camera and prevents light from being reflected off the camera pressure plate and back into the film. This last layer is removed during processing.

Each layer of photo-sensitive emulsion incorporates a dye which reacts with chemicals in the processing bath to color that particular layer as required. These dyes are called 'color couplers'. In the case of negative-positive type films these are the complementary colors of the various layers, i.e. in color negative type filmstock the 'blue' (top) layer is given a yellow dye image.

In color negative filmstock the four layers that do most of the work are:

1. The top photo-sensitive layer which is a silver-halide emulsion that is sensitive only to blue light. This layer is combined with a colorless yellow coupler. After processing this layer produces a yellow dye record of the blue colored elements of the original scene.

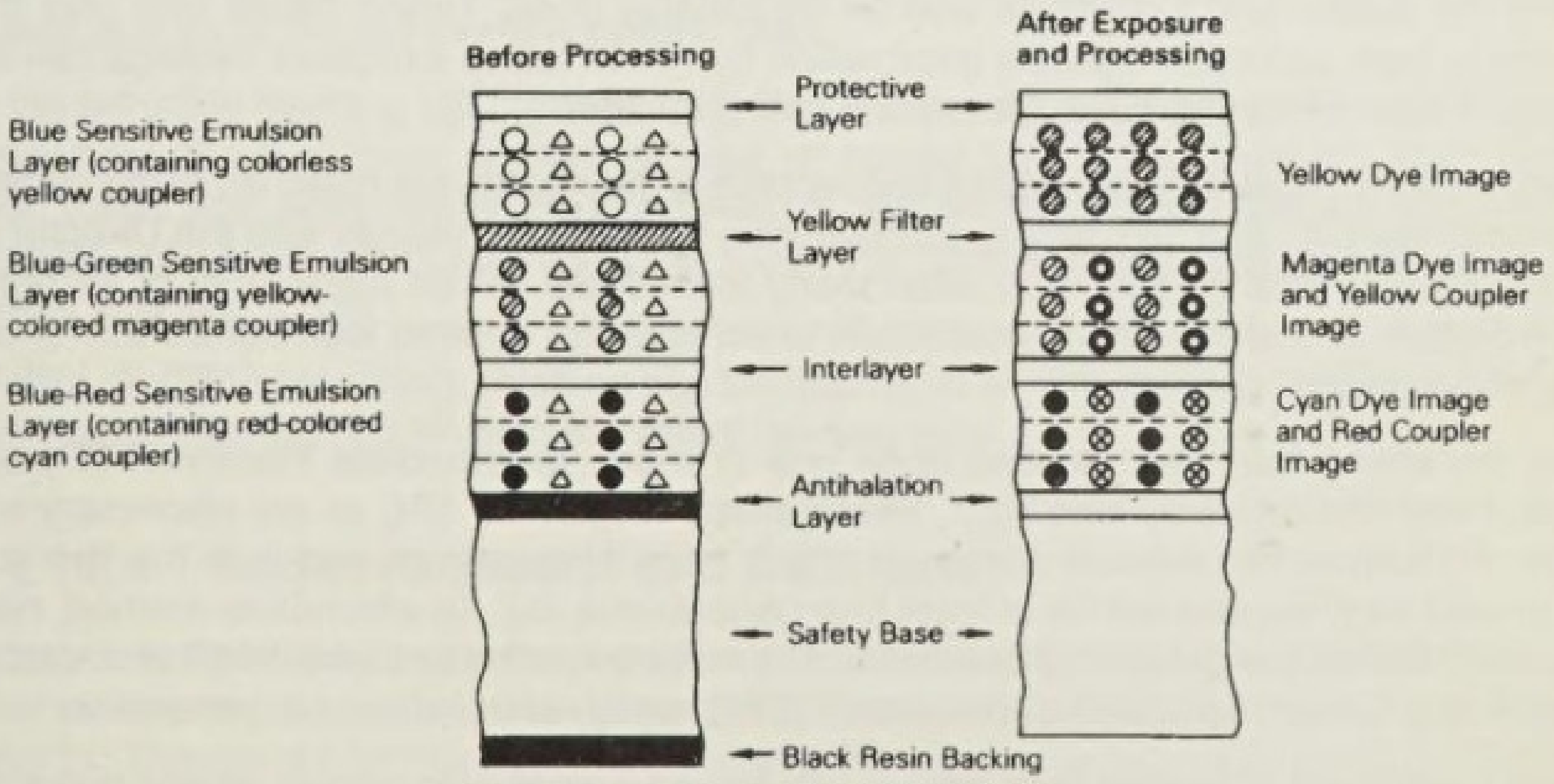
2. The second principal layer is a yellow (minus blue) light filter which stops all blue light passing to the bottom two photo-sensitive layers during exposure. This layer is dissolved away during the developing process.

3. The third principal layer is a silver-halide emulsion which is sensitive to blue and green light. This layer is combined with a yellow colored magenta coupler. Since the blue light has already been deleted by the yellow filter this layer reacts only to green light. After processing this layer is dyed magenta (blue - red) by the coupler.

4. The principal layer next to the film base is a blue - red sensitive emulsion combined with a red colored cyan coupler. This layer records the red light. After processing this layer is dyed cyan (blue - green).

The color balance achieved by this method is not perfect, the cyan layer absorbing some unwanted green and some unwanted blue light and the magenta dye absorbing some unwanted blue. To overcome this problem the color couplers themselves are colored, the middle (magenta) layer a pale yellow color and the bottom (cyan) layer a pale orange–red color. This accounts for the overall orange tint of a color negative. When printed the overall tint counters similar errors in the positive film and results in a perfect color balance.

In color reversal film the blue image is made up of magenta and cyan dyes, the greens from yellow and cyan and the reds from yellow and magenta.


Before Processing
After Exposure and Processing
Blue Sensitive Emulsion Layer (containing colorless yellow coupler)
Blue-Green Sensitive Emulsion Layer (containing yellow-colored magenta coupler)
Blue-Red Sensitive Emulsion Layer (containing red-colored cyan coupler)
Protective Layer
Yellow Filter Layer
Interlayer
Antihalation Layer
Safety Base
Black Resin Backing
Yellow Dye Image
Magenta Dye Image and Yellow Coupler Image
Cyan Dye Image and Red Coupler Image

Film structure diagram published by Fuji Photo Film Co.

11.10 NOTES ON COLOR FILM PROCESSING

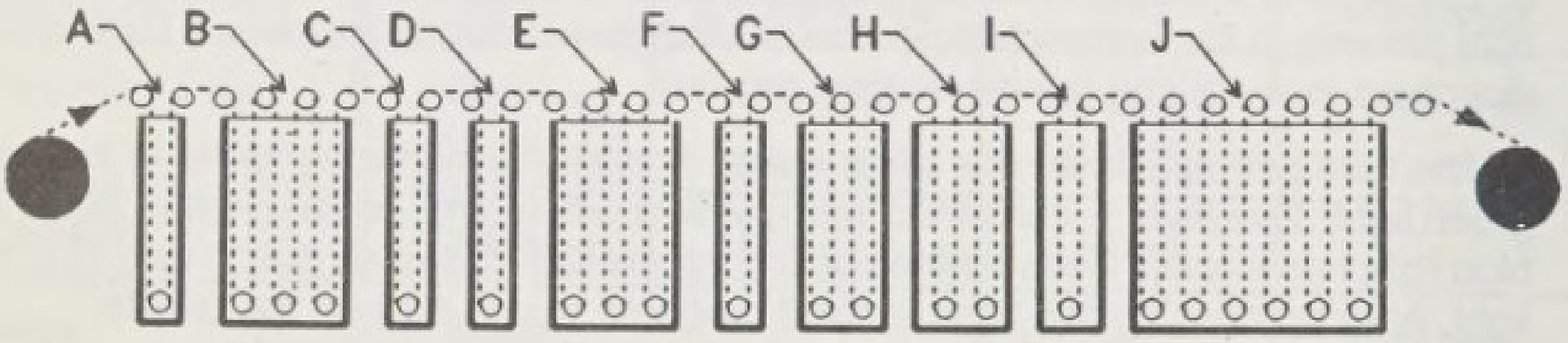
All color negative films, made by whichever manufacturer, are developed by the same ECN-2 process which was first introduced in 1973.

Before the development of the latent image begins the film is thoroughly wetted with a special solution which also dissolves away most of the anti-halo backing. Rotating scrubbing brushes then remove any that remains.

When color film is developed the latent images formed on the layers of silver halide crystals are converted into metallic silver by the action of the film developing chemicals. At the same time the development process couples the various dyes to the exposed silver to form a colored image. The more the exposure to light the denser the silver image and the darker the color.

After passing through a 'stop' bath, followed by a wash, to stop the action of the developer and to wash away those chemicals, the film is then run through a bleaching bath to return the metallic silver back to silver halide. A further bath of warm water, a 'fix' bath and a thorough washing removes all of the silver halide chemicals out of the film leaving just the dye images. A final 'stabilizer' bath ensures a permanent image.

The entire process is done at high temperature (100° - 106°F, 38° - 42°C), takes about 20 minutes and a single machine has a throughput of about 6000 ft (2000m) per hour.



ECN-2 NEGATIVE DEVELOPING PROCESS: A. Pre-bath and Backing Removal; B. Color Developer (3 mins); C. Stop-bath; D. Wash; E. Bleach (3 mins); F. Wash; G. Fix (2 mins); H. Wash (2 mins); I. Stabilizer; J. Drying (6 mins).

Normally developed color film has no remaining silver. Laboratories recover the metallic silver from the fixing and final washing processes and sell it to refiners who in turn sell it back to the filmstock manufacturers. This makes for an environmentally friendly cycle.

After the negative has been processed the selected takes are separated out and an initial print is made. This print is used for 'dailies' or 'rushes' screenings and then becomes the 'cutting copy'. Very often the same print goes on to be used for sound matching and dubbing purposes.

Whether the initial print is 'timed' or 'graded' is optional. There are those who prefer to have a 'one light' print on grounds of economy and because it shows what is coming out of the camera in its raw state. There are also those who prefer to have timed dailies on the grounds that the first impression that many people involved with the film will get is on seeing the dailies and it might as well be reasonably good. Timed dailies also give the DP timing light and color balance information by which future exposure settings can be judged. It also forms the basis for the first trial print later.

When the film has been finally edited and recorded, the negative is matched to the cutting print and 'neg cut'. The final timing process then takes place, usually with the Director of Photography in attendance. Very often many trial copies will be made both of sections of the picture and of the entire production to achieve the desired look before the 'show copy' is produced.

Once the timing has been agreed upon one or more 'Intermediate Positives' (IP) are made. From this as many 'one light' 'Intermediate Negatives' (IN) as are necessary are made. All feature film release prints are made from IN negatives and thus the film you see in your local theater will be at least four generations old. An alternative method, now little used due to the great improvements that have been made to the IN/IP process, is the use of a 'Color Reversal Internegative' (CRI), which eliminates one generation.

Original negatives of feature films are usually stored in special temperature and humidity controlled vaults to preserve their dye images. In the case of important motion pictures 'Color Separation Positives' will be made as a further insurance that the original look will be preserved for posterity.

11.11 NOTES ON CUSTOM COLOR FILM PROCESSING

Filmstock manufacturers go to immense lengths to produce filmstocks that reproduce colors and tones and hues and densities that are faithful to the original. Having done that they also ensure that any approved motion picture film laboratory anywhere in the world will process those films to within very tight limits and to strictly controlled standards.

However, there are occasions when film makers wish to achieve a non-standard look about their films which is not a true reproduction of the way things really are and sometimes this can best be achieved by the application of creativity in the processing laboratory. A few laboratories can modify the standard processing to produce a customized look.

It goes without saying that modified processing should never be attempted without exhaustive tests beforehand and with close cooperation with all concerned, especially the color timer. If the process is to be applied individually to each and every print the end user needs to be satisfied that the process will be controllable and repeatable over a long print run.

11.11.1 Forced/pulled development

Negative or positive film may be 'pushed' or 'force developed' either by spending longer in the developer solution or by the developer being warmer. The result is a more dense and more contrasty image with enhanced grain size. Similarly, 'pulled' or reduced development will decrease density, contrast and grain size.

11.11.2 Modified bleach

The print bleach bath, which removes the silver and leaves just the colored dye, may be modified or skipped entirely. 'Without bleach' leaves all the silver image in the film, in addition to the dye image. This results in a denser image with all the colors with a greater black content and therefore much desaturated and more contrasty. 'Without bleach accelerator' leaves about 50% of the silver image intact and therefore has reduced effect.

This method does not work satisfactorily with interpositive stock so it must be applied to each final print individually.

Cinematographers using this method are advised to start off with a soft, low contrast image with muted colors and avoid dark maroon reds and navy blues which will tend to blacken in the process. Vivid red lipsticks should also be avoided. The image can be further enhanced by using a controlled amount of diffusion at the time of original photography.

11.11.3 Pre-flashing

Negative or positive film may be exposed to a very low level, uniform, exposure to white or colored light before or after exposure. Negative film may be flashed either in the camera or by the laboratory. The result is an increased exposure level, more detail in the shadow areas and a decreased overall contrast ratio.

If the negative flashing light is colored, rather than white, it will affect the shadow areas more than the highlights. It tends to give an overall hue to backgrounds while leaving skin tones and skies relatively untouched. If positive print film is flashed with white or colored light it will affect the highlights more than the shadows, slightly filling the white areas and skin tones.

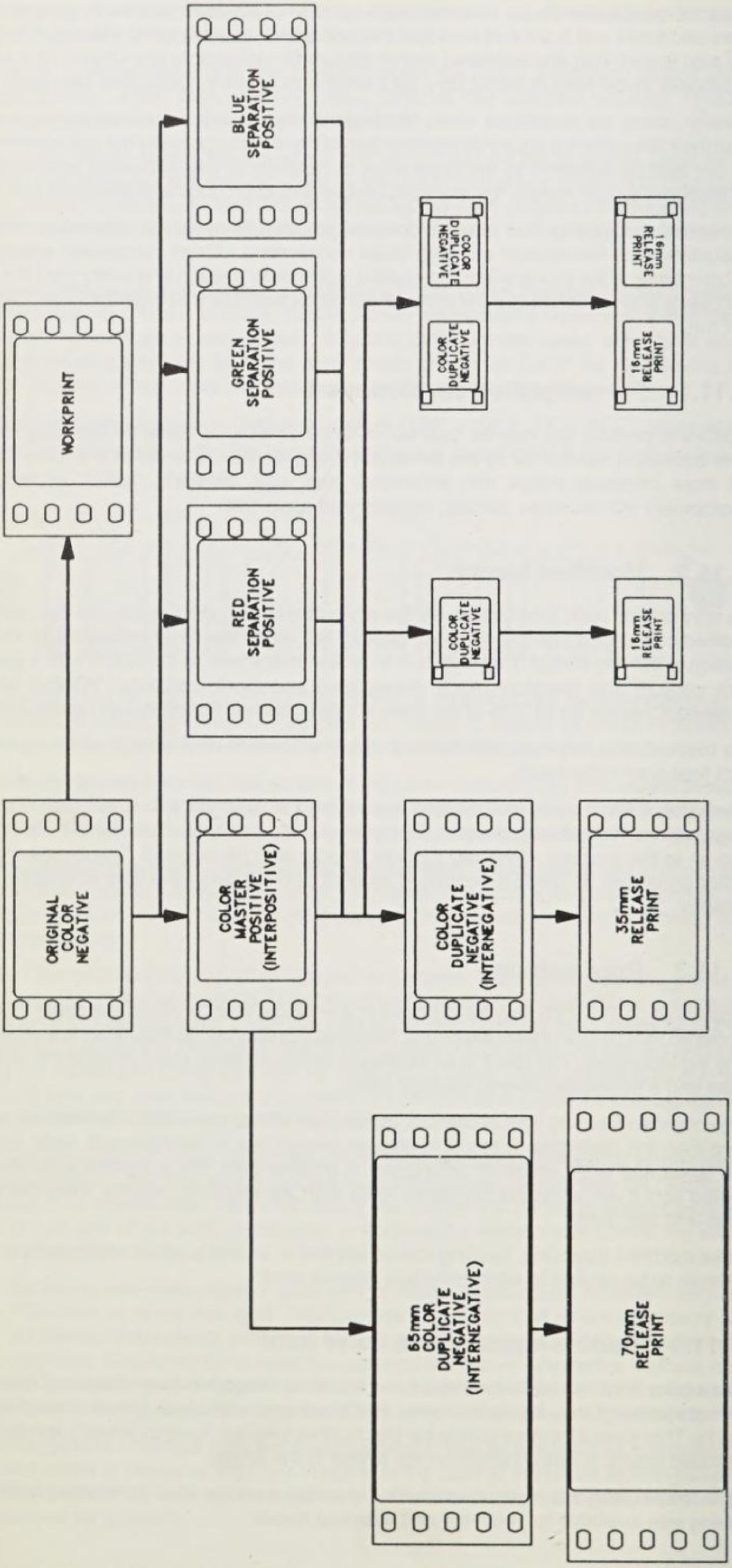
Unlike modified bleaching, flashing can be applied to an interpositive and therefore does not have to be applied to each individual release print.

11.11.4 Redevelopment in a B&W bath

After a color print has been developed and the silver image has been bleached out in the normal manner it may be redeveloped in a black and white bath before it reaches the final fix. This gives a lot more guts to the blacks (they become 'funeral glossy') and darkens saturated colors. It has no effect on the whites in the image.

Prints made using this method are more expensive as more silver is retained in the film leaving less available for recovery and eventual resale.

11.12 CAMERA TO SHOW-PRINT FLOW CHART



From camera to show-print, the different paths an image can take

11.13 LATENT-IMAGE FILM EDGE INFORMATION

All camera filmstocks have standardized information printed along one edge of the film outside the perforations. The information is exposed onto the film at the time of perforation. Being a latent image it cannot be seen until the film has been processed. The data is both human readable (alphanumeric) and machine readable (barcode).

The human-readable information is in two groups which are repeated every foot of film (16 frames or 64 perfs of 35mm, 40 frames of 16mm). The first, and most prominent, gives the footage count or key number (an eight digit number in two groups of four) which advances by one digit every foot, the film type identification number (a two digit number which corresponds to the last two digits of the film type), the film identification code and the manufacturer's identification code (A=Agfa etc.). The second set of (smaller) numbers gives the manufacturer's code, the master roll number, the emulsion number, the product number and the manufacturer's name. There are slight differences in the layouts between different manufacturers and between 16mm and 35mm film.

Film is always supplied with the lowest number on the outside of the roll.

The machine-readable code takes the form of a barcode display which appears twice every foot and incorporates the manufacturer's ID number, the film type, the count number and the offset in perfs.

Once every foot there is a Zero Frame Reference Mark which identifies the frame above it as the zero-frame specified by the human-readable key number (which precedes it) and the machine-readable barcode (which follows it). The Zero Frame Reference Mark takes the form of a filled circle placed alongside the center of a perforation.

The mid-foot human-readable key number is half the height of the normal key numbers and is followed by '+32' to indicate that it is that footage number plus 32 perforations.

Where it does not interfere with any other edgeprint information a short line Frame Index Marker appears every four perforations to help locate the position of the frame line in low light scenes.

Finally there are Matching Check Symbols, randomly inserted symbols to help verify that the negative and working print are properly matched.

It is a part of this standard that the opposite edge of the film be left clear by the manufacturers so that customers may use it for their own edge numbering purposes, whether it be camera generated or printed on.

11.13.1 Filmstock identification codes and letters

Agfa

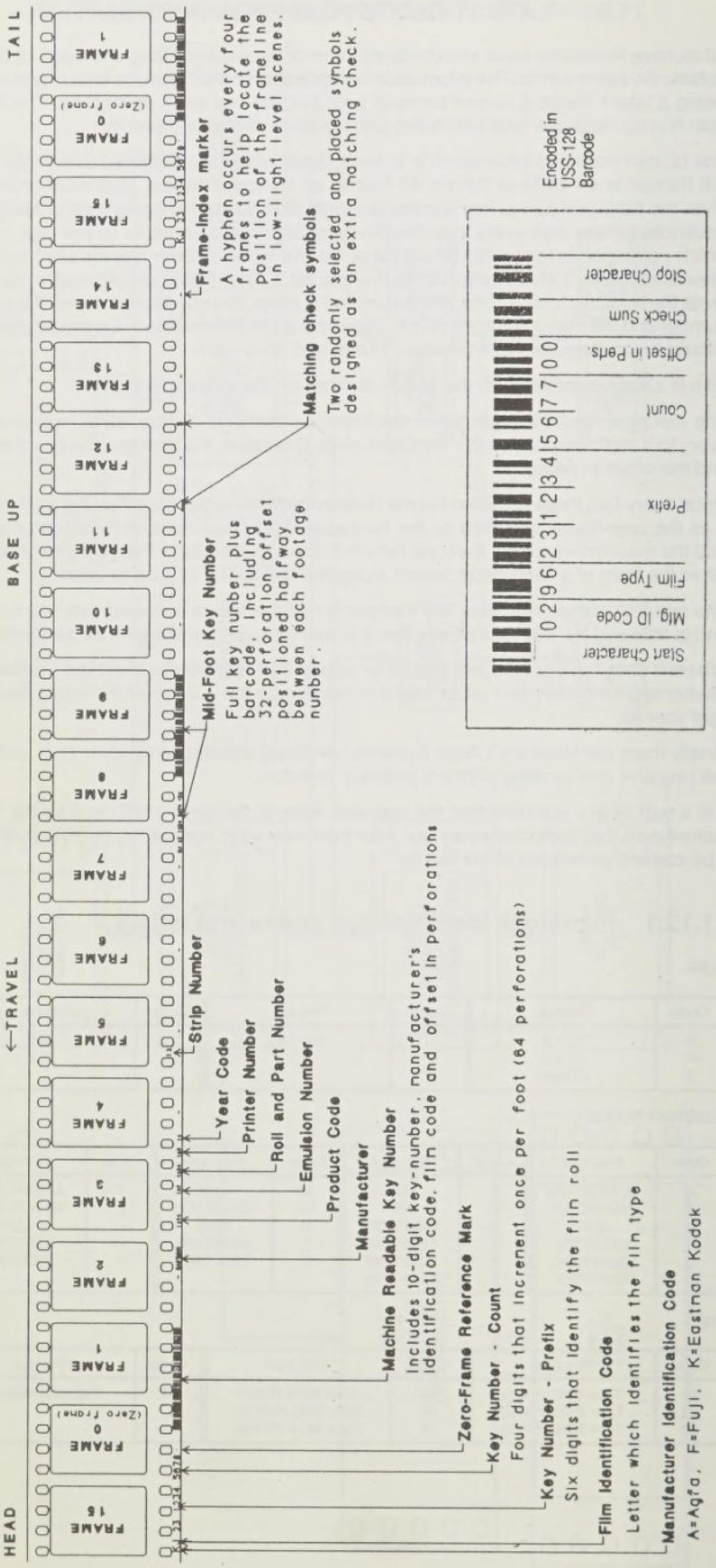
Code	Film type	Code	Film type	Code	Film type
N	XT100	H	Pan 250	D	362
F	XT320			G	553
S	XTS400				

Eastman Kodak

Code	Film type	Code	Film type	Code	Film type	Code	Film type
A	5243/SO 420	F	5295	M	7248	Y	All B&W SO's
A	7243/SO 443	G	5294	N	7292/SO175	Z	All ECN SO's
B	5247	H	5231/7231	S	7272	-	5373
C	5297/7297	J	5296/7296	T	5298/7298	-	5385/7385
D	5234/7234	K	5245/7245	V	5244/7244	-	5386/7386
E	5222/7222	L	5224/7293				

Fuji

Code	Film type	Code	Film type	Code	Film type
10	Type 8510 (F-64)	50	Type 8550 (F250)	13	Fuji Intermediate
20	Type 8520 (F64D)	60	Type 8560 (F250D)		
30	Type 8530 (F125)	14	Type 8514 (F-500)		


HEAD
←TRAVEL
BASE UP
TAIL
FRAME 15
FRAME 0 (Zero Frame)
FRAME 1
FRAME 2
FRAME 3
FRAME 4
FRAME 5
FRAME 6
FRAME 7
FRAME 8
FRAME 9
FRAME 10
FRAME 11
FRAME 12
FRAME 13
FRAME 14
FRAME 15
FRAME 0 (Zero Frame)
FRAME 1
KJ 23 1234 5678
Manufacturer Identification Code
A=Agfa, F=Fuji, K=Eastman Kodak
Film Identification Code
Letter which identifies the film type
Key Number - Prefix
Six digits that identify the film roll
Key Number - Count
Four digits that increment once per foot (64 perforations)
Zero-Frame Reference Mark
Machine Readable Key Number
Includes 10-digit key-number, manufacturer's identification code, film code and offset in perforations
Manufacturer
Product Code
Emulsion Number
Roll and Part Number
Printer Number
Year Code
Strip Number
Mid-Foot Key Number
Full key number plus barcode, including 32-perforation offset positioned halfway between each footage number.
Matching check symbols
Two randomly selected and placed symbols designed as an extra matching check.
Frame-Index marker
A hyphen occurs every four frames to help locate the frameline position in low-light level scenes.
Start Character
Mfg. ID Code
Film Type
Prefix
Count
Offset in Perfs.
Check Sum
Stop Character
0 2 9 6 2 3 1 2 3 4 5 6 7 7 0 0
Encoded in USS-128 Barcode

The standardized latent image film edge information layout

11.14 NOTES ON FILM CAN LABELS

Vital information relating to each and every roll of unexposed filmstock is written on the label of the can. All film can labels display the following:

Manufacturer's name, product name and product reference number.

Color balance of the filmstock, i.e. daylight or tungsten and the correction filter required for the alternative color balance.

The EI and exposure ratings of the filmstock. Filmstocks distributed in Europe also display the DIN standard (German) rating.

The manufacturers' batch data reference number from which can be traced the emulsion batch number, the master roll number, the slit number, the cut number and the perforator number. In the event of any believed filmstock fault it is very important to be able to quote this reference number.

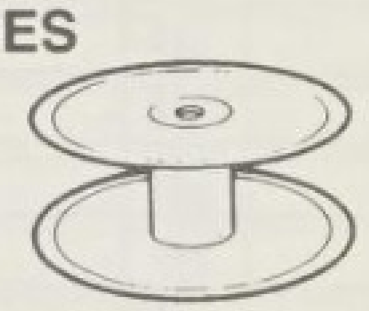
In addition to distinctive labels manufacturers also sometimes color code the packaging tape which seals the cans:

Eastman Kodak:

Gold:	Eastman EXR 50D Film 7245/5245
Green:	Eastman EXR 100T Film 7248/5248
Mauve:	Eastman EXR 200T Film 7293/5293
Red:	Eastman EXR 500T Film 7296/5296

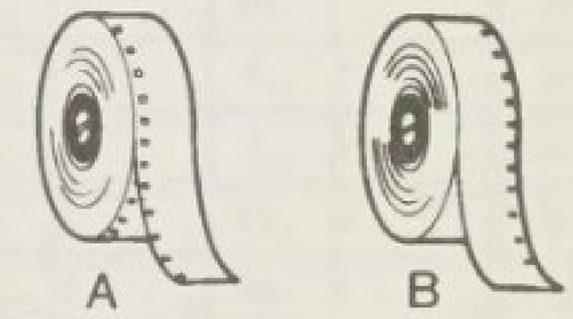
11.15 NOTES ON ROLL SIZES

Most 35mm camera film is available in 61m (200ft), 122m (400ft) and 305m (1000ft) rolls wound emulsion-in on a 2in core. 500ft and 2000ft rolls can be supplied to special order. Many types can also be supplied on 'No. 10' 100ft daylight loading spools.



'No. 10' 35mm 100' spool

Most 16mm camera film is available in 61m (200ft), 122m (400ft) and 366m (1200ft) rolls wound emulsion-in on a 2in core and on 100ft, 200ft and 400ft daylight loading spools. 16mm camera film is available single-perf B winding (1R-7.605mm, 1R-2994) or double perf (2R-7.605, 2R-2994). B wound single-perf 16mm film is also available with a magnetic stripe for com-mag recording.



16mm SINGLE PERF ROLL WINDINGS (emulsion in)

Laboratories normally use 'A' winding film for contact printing and 'B' winding for optical printing.

11.16 NOTES ON STORAGE

Negative color filmstock may undergo changes in photographic properties as a result of prolonged and incorrect storage. In particular, heat and moisture should be avoided. Ideally, for periods of up to three months film should be stored at temperatures below 13°C (55°F) and for up to twelve months at -23° to -18°C (-10° to 0°F). The Relative Humidity should not exceed 60%.

Rawstock that has been refrigerated before use should remain in its sealed package until it is brought into equilibrium with its working temperature, otherwise condensation may result.

Once exposed, filmstock should be processed as soon as possible. If there is to be any unavoidable delay it should be stored as for unexposed film.

To ensure long term archival storage with a minimum of color fading, color negative should be stored in the dark at temperatures below 20°C (68°F) and at a relative humidity of 40 to 50%.

11.17 FILM LENGTH/RUNNING TIME LOOK-UP TABLES

FILM LENGTH TO RUNNING TIME (FEET)

35mm × 4 perforations and 35mm × 3 perforations

	35mm × 4 perforations									35mm × 3 perforations								
	24fps			25fps			30fps			24fps			25fps			30fps		
Feet	**hr**	**min**	**sec**	hr	min	sec	hr	min	sec	hr	min	sec	hr	min	sec	hr	min	sec
1			0.7			0.6			0.5			0.9			0.9			0.7
2			1			1			1			2			2			1
3			2			2			2			3			3			2
4			3			3			2			4			3			3
5			3			3			3			4			4			4
6			4			4			3			5			5			4
7			5			4			4			6			6			5
8			5			5			4			7			7			6
9			6			6			5			8			8			6
10			7			6			5			9			9			7
20			13			13			11			18			17			14
30			20			19			16			27			26			21
40			27			26			21			36			34			28
50			33			32			27			44			43			36
60			40			38			32			53			51			43
70			47			45			37		1	2			60			50
80			53			51			43		1	11		1	8			57
90		1	0			58			48		1	20		1	17		1	4
100		1	7		1	4			53		1	29		1	25		1	11
200		2	13		2	8		1	47		2	58		2	51		2	22
300		3	20		3	12		2	40		4	27		4	16		3	33
400		4	27		4	16		3	33		5	56		5	41		4	44
500		5	33		5	20		4	27		7	24		7	7		5	56
600		6	40		6	24		5	20		8	53		8	32		7	7
700		7	47		7	28		6	13		10	22		9	57		8	18
800		8	53		8	32		7	7		11	51		11	23		9	29
900		10	0		9	36		8	0		13	20		12	48		10	40
1000		11	7		10	40		8	53		14	49		14	13		11	51
2000		22	13		21	20		17	47		29	38		28	27		23	42
3000		33	20		32	0		26	40		44	27		42	40		35	33
4000		44	27		42	40		35	33		59	16		56	53		47	24
5000		55	33		53	20		44	27	1	14	4	1	11	7		59	16
6000	1	6	40	1	4	0		53	20	1	28	53	1	25	20	1	11	7
7000	1	17	47	1	14	40	1	2	13	1	43	42	1	39	33	1	22	58
8000	1	28	53	1	25	20	1	11	7	1	58	31	1	53	47	1	34	49
9000	1	40	0	1	36	0	1	20	0	2	13	20	2	7	60	1	46	40
10000	1	51	7	1	46	40	1	28	53	2	28	9	2	22	13	1	58	31

FILM LENGTH TO RUNNING TIME (FEET), continued

65/70mm, 35mm × 8 perforations, 16mm and Super 8

	65/70mm			35mm × 8 perforations			**16mm**									Super 8		
	24fps			24fps			**24fps**			25fps			30fps			24fps		
Feet	hr	min	sec	hr	min	sec	**hr**	**min**	**sec**	hr	min	sec	hr	min	sec	hr	min	sec
1			0.5			0.3			**1.7**			1.6			1.3			3
2			1			1			**3**			3			3			6
3			2			1			**5**			5			4			9
4			2			1			**7**			6			5			12
5			3			2			**8**			8			7			15
6			3			2			**10**			10			8			18
7			4			2			**12**			11			9			21
8			4			3			**13**			13			11			24
9			5			3			**15**			14			12			27
10			5			3			**17**			16			13			30
20			11			7			**33**			32			27		1	0
30			16			10			**50**			48			40		1	30
40			21			13		**1**	**7**		1	4			53		2	0
50			27			17		**1**	**23**		1	20		1	7		2	30
60			32			20		**1**	**40**		1	36		1	20		3	0
70			37			23		**1**	**57**		1	52		1	33		3	30
80			43			27		**2**	**13**		2	8		1	47		4	0
90			48			30		**2**	**30**		2	24		2	0		4	30
100			53			33		**2**	**47**		2	40		2	13		5	0
200		1	47		1	7		**5**	**33**		5	20		4	27		10	0
300		2	40		1	40		**8**	**20**		8	0		6	40		15	0
400		3	33		2	13		**11**	**7**		10	40		8	53		20	0
500		4	27		2	47		**13**	**53**		13	20		11	7		25	0
600		5	20		3	20		**16**	**40**		16	0		13	20		30	0
700		6	13		3	53		**19**	**27**		18	40		15	33		35	0
800		7	7		4	27		**22**	**13**		21	20		17	47		40	0
900		8	0		5	0		**25**	**0**		24	0		20	0		45	0
1000		8	53		5	33		**27**	**47**		26	40		22	13		50	0
2000		17	47		11	7		**55**	**33**		53	20		44	27	1	40	0
3000		26	40		16	40	**1**	**23**	**20**	1	20	0	1	6	40	2	30	0
4000		35	33		22	13	**1**	**51**	**7**	1	46	40	1	28	53	3	20	0
5000		44	27		27	47	**2**	**18**	**53**	2	13	20	1	51	7	4	10	0
6000		53	20		33	20	**2**	**46**	**40**	2	40	0	2	13	20	5	0	0
7000	1	2	13		38	53	**3**	**14**	**27**	3	6	40	2	35	33	5	50	0
8000	1	11	7		44	27	**3**	**42**	**13**	3	33	20	2	57	47	6	40	0
9000	1	20	0		50	0	**4**	**10**	**0**	4	0	0	3	20	0	7	30	0
10000	1	28	53		55	33	**4**	**37**	**47**	4	26	40	3	42	13	8	20	0

FILM RUNNING TIME TO LENGTH (FEET)

35mm × 4 perforations and 35mm × 3 perforations

	35mm × 4 perforations						35mm × 3 perforations					
	24fps		25fps		30fps		24fps		25fps		30fps	
sec	**feet**	**frames**	feet	frames	feet	frames	feet	frames	feet	frames	feet	frames
1	**1**	**8**	1	9	1	14	1	3	1	4	1	9
2	**3**	**0**	3	2	3	12	2	5	2	7	2	17
3	**4**	**8**	4	11	5	10	3	8	3	11	4	5
4	**6**	**0**	6	4	7	8	4	11	4	15	5	13
5	**7**	**8**	7	13	9	6	5	13	5	18	7	1
6	**9**	**0**	9	6	11	4	6	16	7	1	8	9
7	**10**	**8**	10	15	13	2	7	19	8	4	9	18
8	**12**	**0**	12	8	15	0	9	0	9	8	11	5
9	**13**	**8**	14	1	16	14	10	3	10	12	12	14
10	**15**	**0**	15	10	18	12	11	5	11	15	14	1
20	**30**	**0**	31	4	37	8	22	11	23	9	28	3
30	**45**	**0**	46	14	56	4	33	16	35	3	42	4
40	**60**	**0**	62	8	75	0	45	0	46	19	56	5
50	**75**	**0**	78	2	93	12	56	5	58	13	70	7
60	**90**	**0**	93	12	112	8	67	11	70	7	84	8
min												
1	**90**		94		113		68		70		84	
2	**180**		188		225		135		141		169	
3	**270**		281		338		203		211		253	
4	**360**		375		450		270		281		338	
5	**450**		469		563		338		352		422	
6	**540**		563		675		405		422		506	
7	**630**		656		788		473		492		591	
8	**720**		750		900		540		563		675	
9	**810**		844		1013		608		633		759	
10	**900**		938		1125		675		703		844	
20	**1800**		1875		2250		1350		1406		1688	
30	**2700**		2813		3375		2025		2109		2531	
40	**3600**		3750		4500		2700		2813		3375	
50	**4500**		4688		5625		3375		3516		4219	
60	**5400**		5625		6750		4050		4219		5063	
hrs												
1	**5400**		5625		6750		4050		4219		5063	
2	**10800**		11250		13500		8100		8438		10125	
3	**16200**		16875		20250		12150		12656		15188	
4	**21600**		22500		27000		16200		16875		20250	
5	**27000**		28125		33750		20250		21094		25313	

Note: Lengths up to 60 seconds running time are rounded off to the nearest frame. Above 1 minute lengths are rounded off to the nearest foot.

FILM RUNNING TIME TO LENGTH (FEET), continued

65/70mm, 35mm × 8 perforations, 16mm and Super 8

	65/70mm		35mm × 8 perf		**16mm**						Super 8	
	24fps		24fps		**24fps**		25fps		30fps		24fps	
sec	feet	frames	feet	frames	**feet**	**frames**	feet	frames	feet	frames	feet	frames
1	1	11	3	0	**0**	**24**	0	25	0	30	0	24
2	3	10	6	0	**1**	**8**	1	10	1	20	0	48
3	5	8	9	0	**1**	**32**	1	35	2	10	1	0
4	7	6	12	0	**2**	**16**	2	20	3	0	1	24
5	9	5	15	0	**3**	**0**	3	5	3	30	1	48
6	11	3	18	0	**3**	**24**	3	30	4	20	2	0
7	13	2	21	0	**4**	**8**	4	15	5	10	2	24
8	15	0	24	0	**4**	**32**	5	0	6	0	2	48
9	16	11	27	0	**5**	**16**	5	25	6	30	3	0
10	18	10	30	0	**6**	**0**	6	10	7	20	3	24
20	37	6	60	0	**12**	**0**	12	20	15	0	6	48
30	56	3	90	0	**18**	**0**	18	30	22	20	10	0
40	75	0	120	0	**24**	**0**	25	0	30	0	13	24
50	93	10	150	0	**30**	**0**	31	10	37	20	16	48
60	112	6	180	0	**36**	**0**	37	20	45	0	20	0
min												
1	113		180		**36**		38		45		20	
2	225		360		**72**		75		90		40	
3	338		540		**108**		113		135		60	
4	450		720		**144**		150		180		80	
5	563		900		**180**		188		225		100	
6	675		1080		**216**		225		270		120	
7	788		1260		**252**		263		315		140	
8	900		1440		**288**		300		360		160	
9	1013		1620		**324**		338		405		180	
10	1125		1800		**360**		375		450		200	
20	2250		3600		**720**		750		900		400	
30	3375		5400		**1080**		1125		1350		600	
40	4500		7200		**1440**		1500		1800		800	
50	5625		9000		**1800**		1875		2250		1000	
60	6750		10800		**2160**		2250		2700		1200	
hrs												
1	6750		10800		**2160**		2250		2700		1200	
2	13500		21600		**4320**		4500		5400		2400	
3	20250		32400		**6480**		6750		8100		3600	
4	27000		43200		**8640**		9000		10800		4800	
5	33750		54000		**10800**		11250		13500		6000	

Note: Lengths up to 60 seconds running time are rounded off to the nearest frame. Above 1 minute lengths are rounded off to the nearest foot.

FILM LENGTH TO RUNNING TIME (METERS)

35mm × 4 perforations and 35mm × 3 perforations

	35mm × 4 perforations									35mm × 3 perforations								
	24fps			25fps			30fps			24fps			25fps			30fps		
Meters	**hr**	**min**	**sec**	hr	min	sec	hr	min	sec	hr	min	sec	hr	min	sec	hr	min	sec
0.5			1.1			1			0.9			1.5			1.4			1.2
1			2.2			2.1			1.7			2.9			2.8			2.3
2			4			4			3			6			6			5
3			7			6			5			9			8			7
4			9			8			7			12			11			9
5			11			10			9			15			14			12
6			13			13			10			17			17			14
7			15			15			12			20			20			16
8			17			17			14			23			22			19
9			20			19			16			26			25			21
10			22			21			17			29			28			23
20			44			42			35			58			56			47
30		1	6		1	3			52		1	27		1	24		1	10
40		1	27		1	24		1	10		1	57		1	52		1	33
50		1	49		1	45		1	27		2	26		2	20		1	57
60		2	11		2	6		1	45		2	55		2	48		2	20
70		2	33		2	27		2	2		3	24		3	16		2	43
80		2	55		2	48		2	20		3	53		3	44		3	7
90		3	17		3	9		2	37		4	22		4	12		3	30
100		3	39		3	30		2	55		4	52		4	40		3	53
200		7	17		6	60		5	50		9	43		9	20		7	47
300		10	56		10	30		8	45		14	35		13	60		11	40
400		14	35		13	60		11	40		19	27		18	40		15	33
500		18	14		17	30		14	35		24	18		23	20		19	27
600		21	52		20	60		17	30		29	10		27	60		23	20
700		25	31		24	30		20	25		34	1		32	40		27	13
800		29	10		27	60		23	20		38	53		37	20		31	6
900		32	48		31	30		26	15		43	45		41	60		34	60
1000		36	27		34	60		29	10		48	36		46	40		38	53
2000	1	12	54	1	9	59		58	20	1	37	13	1	33	19	1	17	46
3000	1	49	22	1	44	59	1	27	29	2	25	49	2	19	59	1	56	39
4000	2	25	49	2	19	59	1	56	39	3	14	25	3	6	38	2	35	32
5000	3	2	16	2	54	59	2	25	49	4	3	1	3	53	18	3	14	25
6000	3	38	43	3	29	58	2	54	59	4	51	38	4	39	58	3	53	18
7000	4	15	10	4	4	58	3	24	8	5	40	14	5	26	37	4	32	11
8000	4	51	38	4	39	58	3	53	18	6	28	50	6	13	17	5	11	4
9000	5	28	5	5	14	57	4	22	28	7	17	26	6	59	57	5	49	57
10000	6	4	32	5	49	57	4	51	38	8	6	3	7	46	36	6	28	50

FILM LENGTH TO RUNNING TIME (METERS), continued

65/70mm, 35mm × 8 perforations, 16mm and Super 8

	65/70mm			35mm × 8 perf			**16mm**									Super 8		
	24fps			24fps			**24fps**			25fps			30fps			24fps		
Meters	hr	min	sec	hr	min	sec	**hr**	**min**	**sec**	hr	min	sec	hr	min	sec	hr	min	sec
0.5			0.9			0.5			**2.7**			2.6			2.2			4.9
1			1.7			1.1			**5.5**			5.2			4.4			9.8
2			3			2			**11**			10			9			20
3			5			3			**16**			16			13			30
4			7			4			**22**			21			17			39
5			9			5			**27**			26			22			49
6			10			7			**33**			31			26			59
7			12			8			**38**			37			31		1	9
8			14			9			**44**			42			35		1	19
9			16			10			**49**			47			39		1	29
10			17			11			**55**			52			44		1	38
20			35			22		**1**	**49**		1	45		1	27		3	17
30			52			33		**2**	**44**		2	37		2	11		4	55
40			10			44		**3**	**39**		3	30		2	55		6	34
50		1	27			55		**4**	**33**		4	22		3	39		8	12
60		1	45		1	6		**5**	**28**		5	15		4	22		9	51
70		2	2		1	17		**6**	**23**		6	7		5	6		11	29
80		2	20		1	27		**7**	**17**		7	0		5	50		13	7
90		2	37		1	38		**8**	**12**		7	52		6	34		14	46
100		2	55		1	49		**9**	**7**		8	45		7	17		16	24
200		5	50		3	39		**18**	**14**		17	30		14	35		32	48
300		8	45		5	28		**27**	**20**		26	15		21	52		49	13
400		11	40		7	17		**36**	**27**		34	60		29	10		5	37
500		14	35		9	7		**45**	**34**		43	45		36	27		22	1
600		17	30		10	56		**54**	**41**		52	30		43	45		38	25
700		20	25		12	46	**1**	**3**	**48**	1	1	14		51	2		54	50
800		23	20		14	35	**1**	**12**	**54**	1	9	59		58	20	1	11	14
900		26	15		16	24	**1**	**22**	**1**	1	18	44	1	5	37	1	27	38
1000		29	10		18	14	**1**	**31**	**8**	1	27	29	1	12	54	1	44	2
2000		58	20		36	27	**3**	**2**	**16**	2	54	59	2	25	49	3	28	5
3000	1	27	29		54	41	**4**	**33**	**24**	4	22	28	3	38	43	5	12	7
4000	1	56	39	1	12	54	**6**	**4**	**32**	5	49	57	4	51	38	6	56	10
5000	2	25	49	1	31	8	**7**	**35**	**40**	7	17	26	6	4	32	8	40	12
6000	2	54	59	1	49	22	**9**	**6**	**48**	8	44	56	7	17	26	10	24	14
7000	3	24	8	2	7	35	**10**	**37**	**56**	10	12	25	8	30	21	12	8	17
8000	3	53	18	2	25	49	**12**	**9**	**4**	11	39	54	9	43	15	13	52	19
9000	4	22	28	2	44	2	**13**	**40**	**12**	13	7	24	10	56	10	15	36	22
10000	4	51	38	3	2	16	**15**	**11**	**20**	14	34	53	12	9	4	17	20	24

Note: Lengths up to 60 seconds running time are rounded off to the nearest frame. Above 1 minute lengths are rounded off to the nearest meter.

FILM RUNNING TIME TO LENGTH (METERS)

35mm × 4 perforations and 35mm × 3 perforations

	35mm × 4 perforations						35mm × 3 perforations					
	24fps		25fps		30fps		24fps		25fps		30fps	
Sec	**meters**	**frames**	meters	frames	meters	frames	meters	frames	meters	frames	meters	frames
1		**24**		25		30		24		25		30
2		**48**		50	1	8		48		50		60
3	**1**	**20**	1	23	1	38	1	2	1	5	1	20
4	**1**	**44**	1	48	2	15	1	26	1	30	1	50
5	**2**	**15**	2	20	2	45	1	50	1	55	2	10
6	**2**	**39**	2	45	3	23	2	4	2	10	2	40
7	**3**	**11**	3	18	4	0	2	28	2	35	3	0
8	**3**	**35**	3	43	4	30	2	52	2	60	3	30
9	**4**	**6**	4	15	5	8	3	6	3	15	3	60
10	**4**	**30**	4	40	5	38	3	30	3	40	4	20
20	**9**	**8**	9	28	11	23	6	60	7	10	8	40
30	**13**	**38**	14	15	17	8	10	20	10	50	12	60
40	**18**	**15**	19	3	22	45	13	50	14	20	17	10
50	**22**	**45**	23	43	28	30	17	10	17	60	21	30
60	**27**	**23**	28	30	34	15	20	40	21	30	25	50
min												
1	**27**	**23**	28	30	34	15	20	40	21	30	25	50
2	**54**	**45**	57	8	68	30	41	10	42	60	51	30
3	**82**	**15**	85	38	102	45	61	50	64	20	77	10
4	**109**	**38**	114	15	137	8	82	20	85	50	102	60
5	**137**	**8**	142	45	171	23	102	60	107	10	128	40
6	**164**	**30**	171	23	205	38	123	30	128	40	154	20
7	**192**	**0**	200	0	240	0	144	0	150	0	180	0
8	**219**	**23**	228	30	274	15	164	40	171	30	205	50
9	**246**	**45**	257	8	308	30	185	10	192	60	231	30
10	**274**	**15**	285	38	342	45	205	50	214	20	257	10
20	**548**	**30**	571	23	685	38	411	30	428	40	514	20
30	**822**	**45**	857	8	1028	30	617	10	642	60	771	30
40	**1097**	**8**	1142	45	1371	23	822	60	857	10	1028	40
50	**1371**	**23**	1428	30	1714	15	1028	40	1071	30	1285	50
60	**1645**	**38**	1714	15	2057	8	1234	20	1285	50	1542	60
Hrs												
1	**1646**		1715		2057		1234		1286		1543	
2	**3292**		3429		4115		2469		2572		3086	
3	**4938**		5144		6172		3703		3858		4629	
4	**6584**		6858		8230		4938		5144		6172	
5	**8230**		8573		10287		6172		6429		7715	

Note: Lengths up to 60 seconds running time are rounded off to the nearest frame. Above 1 minute lengths are rounded off to the nearest meter.

FILM RUNNING TIME TO LENGTH (METERS), continued

65/70mm, 35mm × 8 perforations, 16mm and Super 8

	65/70mm		35mm × 8 perf		**16mm**						Super 8	
	24fps		24fps		**24fps**		25fps		30fps		24fps	
Sec	meters	frames	meters	frames	**meters**	**frames**	meters	frames	meters	frames	meters	frames
1		24		24		**24**		25		30		24
2	1	6	1	22		**48**		50		60		48
3	1	30	2	20		**72**		75		90		72
4	2	12	3	17		**96**		100		120		96
5	2	36	4	15		**120**		125	1	19		120
6	3	18	5	13	**1**	**13**	1	19	1	49		144
7	4	0	6	11	**1**	**37**	1	44	1	79		168
8	4	24	7	9	**1**	**61**	1	69	1	109		192
9	5	6	8	6	**1**	**85**	1	94	2	8		216
10	5	30	9	4	**1**	**109**	1	119	2	38	1	4
20	11	18	18	8	**3**	**86**	3	106	4	75	2	8
30	17	6	27	13	**5**	**64**	5	94	6	113	3	11
40	22	36	36	17	**7**	**42**	7	82	9	19	4	15
50	28	24	45	21	**9**	**19**	9	69	11	57	5	19
60	34	12	54	25	**10**	**128**	11	57	13	94	6	23
min												
1	34	12	54	25	**10**	**128**	11	57	13	94	6	23
2	68	24	109	24	**21**	**125**	22	114	27	58	12	46
3	102	36	164	23	**32**	**122**	34	39	41	21	18	68
4	137	6	219	22	**43**	**118**	45	96	54	115	24	91
5	171	18	274	21	**54**	**115**	57	22	68	78	30	114
6	205	30	329	20	**65**	**112**	68	78	82	42	36	137
7	240	0	384	19	**76**	**109**	80	4	96	5	42	160
8	274	12	439	18	**87**	**106**	91	61	109	99	48	182
9	308	24	494	17	**98**	**102**	102	118	123	62	54	205
10	342	36	549	16	**109**	**99**	114	43	137	26	60	228
20	685	30	1099	6	**219**	**67**	228	86	274	51	121	220
30	1028	24	1648	22	**329**	**35**	342	130	411	77	182	212
40	1371	18	2198	12	**439**	**3**	457	42	548	102	243	203
50	1714	12	2748	2	**548**	**102**	571	85	685	128	304	195
60	2057	6	3297	19	**658**	**70**	685	128	823	22	365	187
Hrs												
1	2057		3292		**658**		686		823		366	
2	4115		6584		**1317**		1372		1646		732	
3	6172		9876		**1975**		2057		2469		1097	
4	8230		13168		**2634**		2743		3292		1463	
5	10287		16459		**3292**		3429		4115		1829	

Note: Lengths up to 60 seconds running time are rounded off to the nearest frame. Above 1 minute lengths are rounded off to the nearest meter.

12 FILTERS

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The 'art' in cinematography lies not only in the creative use of lighting, be it interior or exterior, but also in the equally creative use of filters placed in the matte box in front of the camera lens. Lighting may well be described as an 'additive' process while the use of filters is more of a 'subtractive' one. Together they are by far and away the most important means of image manipulation available to the Director of Photography.

Filter manufacturers will wax lyrical about the wondrous effects they can create on the screen but very few will tell exactly what they are doing to your rays of light on the way.

12.1 FILTER OPTICAL QUALITY

Filters placed in front of a lens, whether they be to control the color, the quantity or the quality of the light, or for the purpose of optical effect, need to be every bit as good optically as the lenses with which they are used. Filters which are not perfectly flat and parallel become lenses in their own right. The filters to be most careful of are the laminated sandwich type where a layer of gelatine is glued between two sheets of glass.

A simple way to test the optical accuracy of a filter is to place it in front of the longest lens you have and compare the focus distance when focused by eye with and without the filter. The longer the focal length of a lens the more important it is that it be optically flat. In an extreme case it may be found that the only satisfactory means of filtering a long telephoto lens is by the use of gelatine filters placed internally or behind.

For use with ultra-wide angle lenses it is necessary also that the filter be thin.

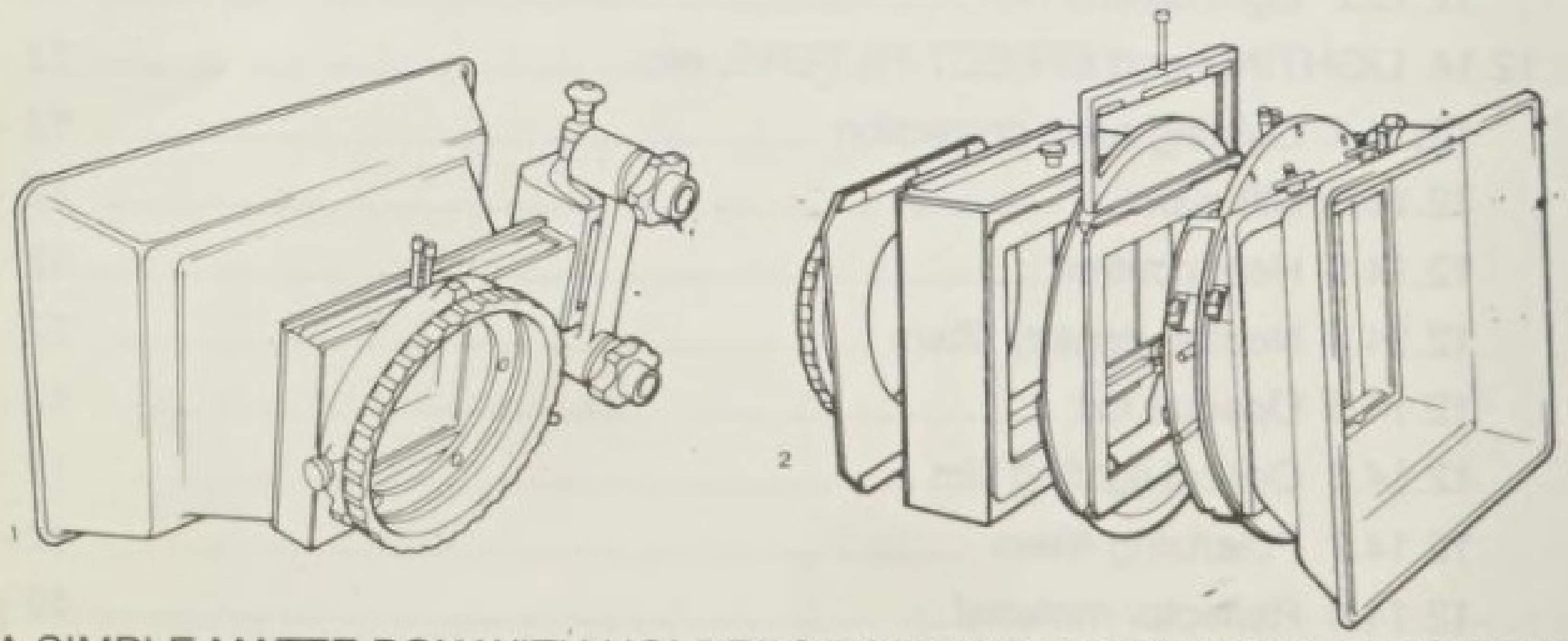
Gelatine filters used behind the lens and just in front of the focal plane must be scrupulously clean and free of even the smallest speck of dust. To avoid finger marks gelatine filters should be cut out of a large sheet to exact size by the use of a filter cutter.

1. A GELATINE FILTER PLACED JUST IN FRONT OF THE FOCAL PLANE OF A CAMERA; 2 A GELATINE FILTER FITTED TO THE REAR OF A LENS; 3. A GELATINE FILTER CUTTER.

The effectiveness of many types of filter is affected by the focal length and the aperture of the lens, the contrast of the lighting and the subject matter and the sharpness of the delineation between areas of bright light and areas of deep shade.

12.2 THE MATTE BOX

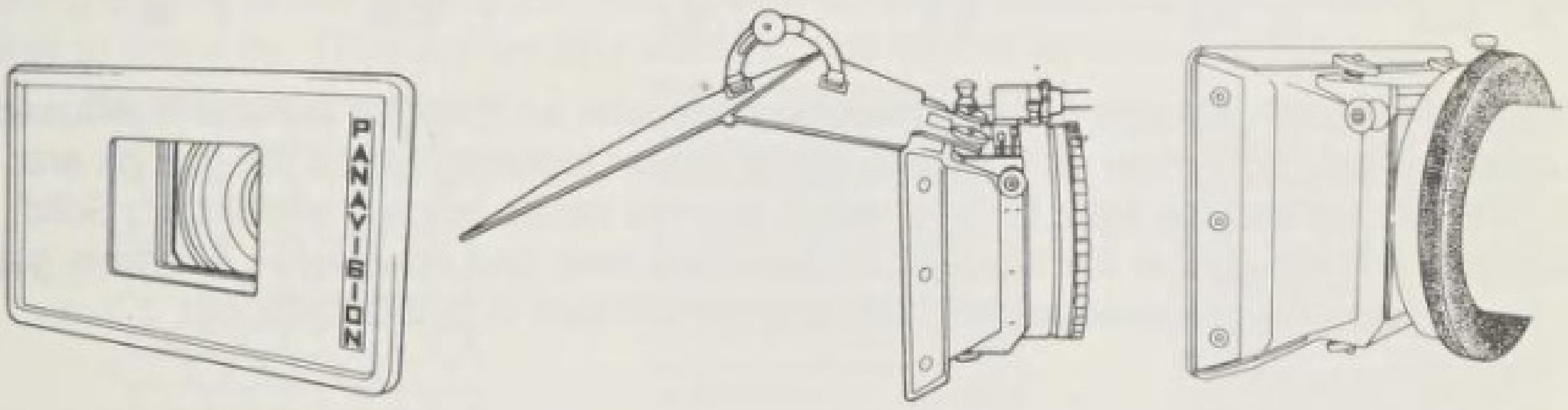
Many types of effect filter require sophisticated matte boxes to enable full advantage to be taken of the control they give. Whereas a simple color balancing filter may need only a fixed single stage filter holder, star filters and polarizers require filter holders that rotate, graduated neutral density and variable color filters need filter holders that can be slid up and down or from side to side or diagonally across the picture and multiple reflections from motor car headlights at night can be avoided if there is one stage that tilts.



1. A SIMPLE MATTE BOX WITH HOLDERS FOR TWO RECTANGULAR AND ONE CIRCULAR (ROTATABLE) FILTER; 2. A MODULAR, MULTISTAGE, MATTE BOX.

Multiple filters should be used with caution due to the loss of transmission caused by internal reflections.

Filters must be protected from stray light just as much as lenses. Mattes can be used over the front of the matte box to mask the opening to suit the lens angle, a top sunshade and adjustable flags can be used to keep light from strong light sources off the filter and a light trap (a 'donut') should be placed between the lens and the rear of the matte box to prevent stray light entering from behind.



1. MATTE BOX MATTE IN POSITION; 2 EXTENSION SUNSHADE FLAP; 3. A DONUT IN POSITION BETWEEN THE LENS AND THE REAR FILTER HOLDER.

12.3 COLOR CONTROL FILTERS

As already noted in Section 14.4 the primary use for camera filters is to control the color temperature and the color quality of the light passing through to the film.

Color temperature filters correct the exposure balance of the light so as to bring all three color layers of the film into the straight part of the sensitometric curve. See Section 14.4.3 for a full listing.

Color correction filters filter out light of a complementary color, allowing proportionately more light of a particular color to pass through to the film. The greater the density of the CC filter the more the overall color will be changed. See Section 14.4.4 for a full listing.

Color enhancement filters block the complementary color of the color which needs to be enhanced. For instance, if it is desired to enhance red colors a filter which will absorb just the cyan colored light (which would desaturate the reds) will leave the reds more intense compared to other colors.

12.4 EFFECT FILTERS

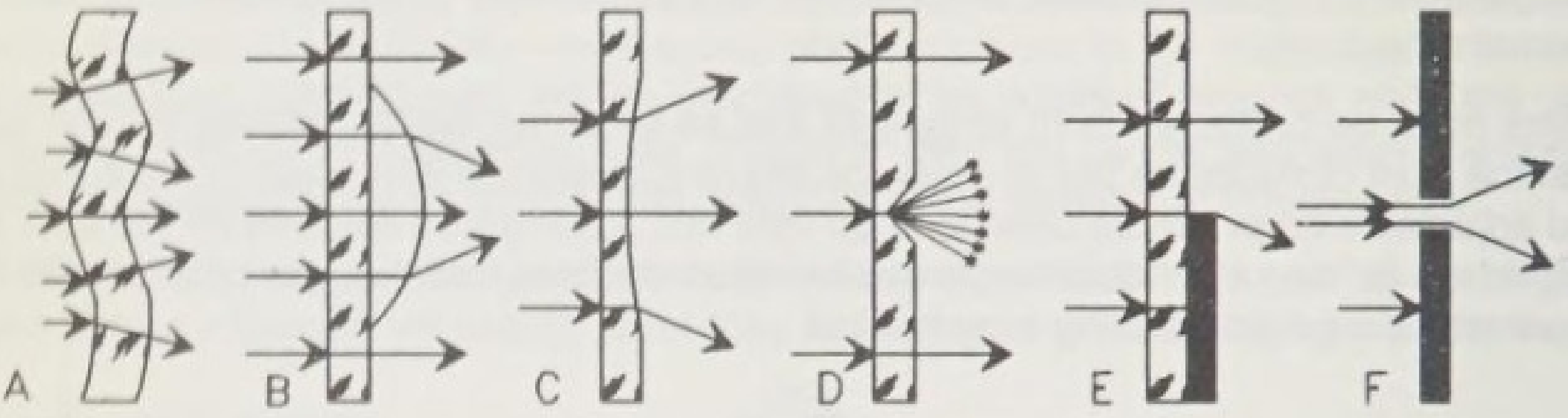
All effect filters degrade the image by some means or other. While optical designers and manufacturers strive to producer sharper and more contrasty lenses with less and less 'veiling glare', cinematographers, aided and abetted by the filter manufacturers, contrive to use more and more effects filters to break down the hardness of the image. If the images were not so good in the first place then the cinematographers would not have as much latitude for control.

If the image is to be defocused this can be done either by means of an irregular surface or by depositing myriad tiny transparent globules onto a glass surface, each of which operates like a tiny diopter lens. Either way, the image is broken up and tiny parts of it are focused in front of or behind the principal plane of focus. What makes the difference between different effects is not only the size, shape and density of the irregularities but also how much clear glass is left between. Both focal length and aperture will affect the effectiveness of such filters.

Another way to defocus an image is by passing the light through a narrow gap or past a solid body so that highlights are 'diffracted' i.e. spread out or bent. In this way highlights are spread into shadows. If there are no bright highlights to be spread into shadows, or dark areas bounded by bright ones, such filters have less effect. The narrower the gaps and the greater the contrasts between light and shade the greater the effect. Shadows can only be spread into highlights by doing it on an optical printer and producing an internegative.

Tiny specks of grit or black flakes will cause the contrast to be lessened by holding back the highlights while having less effect on the shadows. White or colored matter, on the other hand, will reflect light or color into the shadows to produce an overall gray or colored effect.

Filter manufacturers use a combination of means to create their effects and by tight control of the manufacturing process are able to grade the filters into different strengths and to keep consistency between batches of filters.



EFFECT FILTERS: A. Light passing through glass with an irregular surface is diffused in all directions; B. Bumps on the glass cause closer focusing where the bumps are; C. Grooves spread the light; D. 'V' shaped grooves cause colored streaks; E. Solid matter spreads the light at the intersection between clear and opaque; F. A narrow gap between two opaque particles spreads the light in both directions.

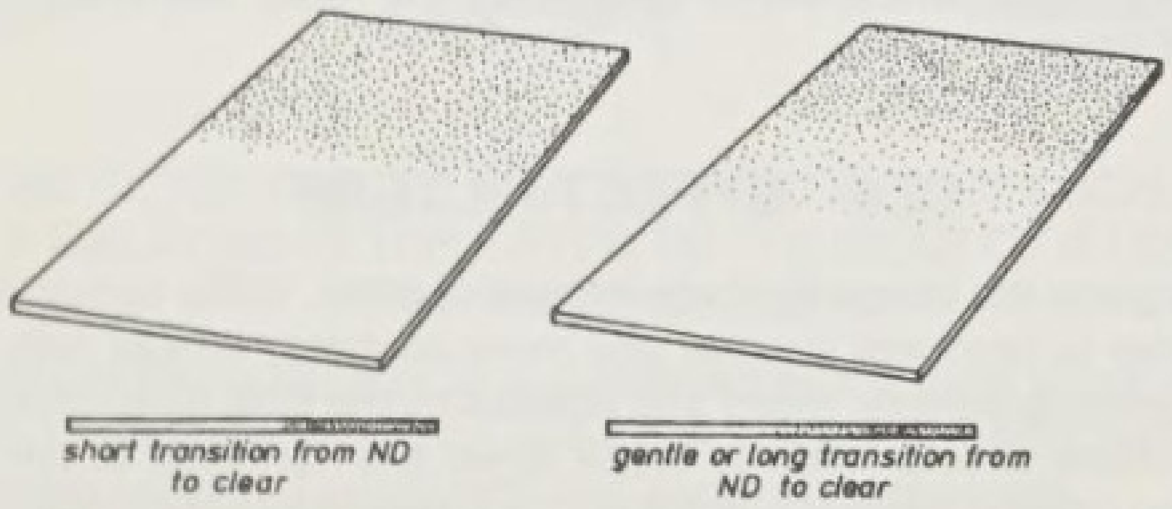
12.4.1 Fog filters

Fog and half fog filters have a finely ground or etched surface which causes the highlights or dominant color to spread into the shadows and veil the image. The more the highlights or the brighter a particular color the greater the effect.

Double fogs are a combination of fog and low contrast. They have much the same effect as fog filters but with little or no flare.

12.4.2 Graduated filters

Graduated neutral density filters may be used to control an over-bright sky background or an ugly foreground or even an obtrusive white wall that needs to have less exposure than the rest of the picture area. Graduated filters are usually obtainable either with a quite hard transition line or with a more gentle or 'soft' blend between the two halves. The harder transmission line is more advantageous where there is a sharp dividing line, as with a seascape. They are also more suitable for use with long focal length lenses. As already noted, graduated filters need be used with a rotatable and slidable matt-box.


short transition from ND to clear
gentle or long transition from ND to clear

1. GRADUATED FILTER WITH HARD TRANSITION LINE; 2. GRADUATED FILTER WITH SOFT TRANSITION.

Blenders and attenuators are overall neutral density (or colored) wedges across the entire length or breadth of the filter.

Colored grads, one half blue or orange, etc. and the other half clear, are much used to make otherwise white and overexposed skies look more attractive. Such filters sometimes incorporate a yellow or orangish center band to simulate a sunset effect.

Half diffusers allow one side of the picture to be softened compared to the other side. These are useful when shooting a two-shot with one person who needs to have facial blemishes softened down and another who needs to remain hard. Sliding or adjustable diffusers, used singly or in pairs from opposite directions, allow diffusion to be added or removed during the course of a take without the transition showing.

Graduated fog filters can be used to give the illusion of added depth to a scene.

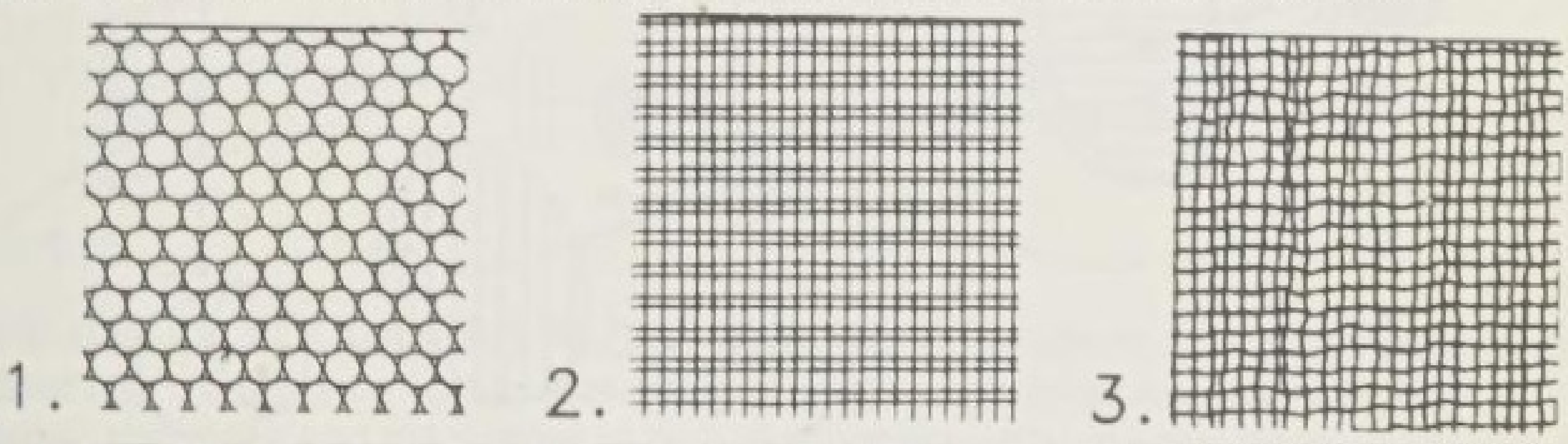
12.4.3 Low contrast filters

Low contrast filters are dotted with myriad fine particles which hold back more of the highlights than the shadows, increasing the black level and reducing the contrast range of a scene. They do not affect the focus as much as do the various diffusing filters.

12.4.4 Nets and voiles

Nets have come to mean an open woven mesh type material with a regular pattern of hexagonal cornered holes. These nets have a gentle diffusing effect and do not affect point source highlights as do nets with a square weave or star filters.

The old type of net was really a voile, a very fine, open-woven, silk netting with irregular square holes in it. Typically it is woven in France and intended for use by milliners as veiling around ladies' hats. Such 'nets' are as old as cinematography itself and not always easy to come by. They are usually used in open frames and much cherished.



1. NET WITH ROUND CORNERS; 2. SILK NET; 3. VOILE WITH IRREGULAR WEAVE.
(All magnified many times)

Voile type nets polarize the light to quite a degree and during the testing period some camera crews take the time to mark each net with its direction of polarization and rotate them when they are on the camera to obtain the best effect. For this reason, too, care should be taken when using them in conjunction with real polarizing filters as the pair, in combination, might well adversely affect the light transmission.

Particularly with short focus lenses and lenses well stopped down, nets need to be placed as close to the lens as possible, so that they do not photograph. Alternatively, nets may be attached to the rear rim of a lens (particularly a zoom lens) using 'snot tape', 1/2" Scotch ATG-924 double sided 'rubber cement' type tape and then cut to size.

Square cornered nets diffract light like star filters but because the lines are thicker tend to hold the highlights back more. White nets can impart a beautiful milkiness to a scene and colored nets can influence the shadows.

12.5 NEUTRAL DENSITY FILTERS

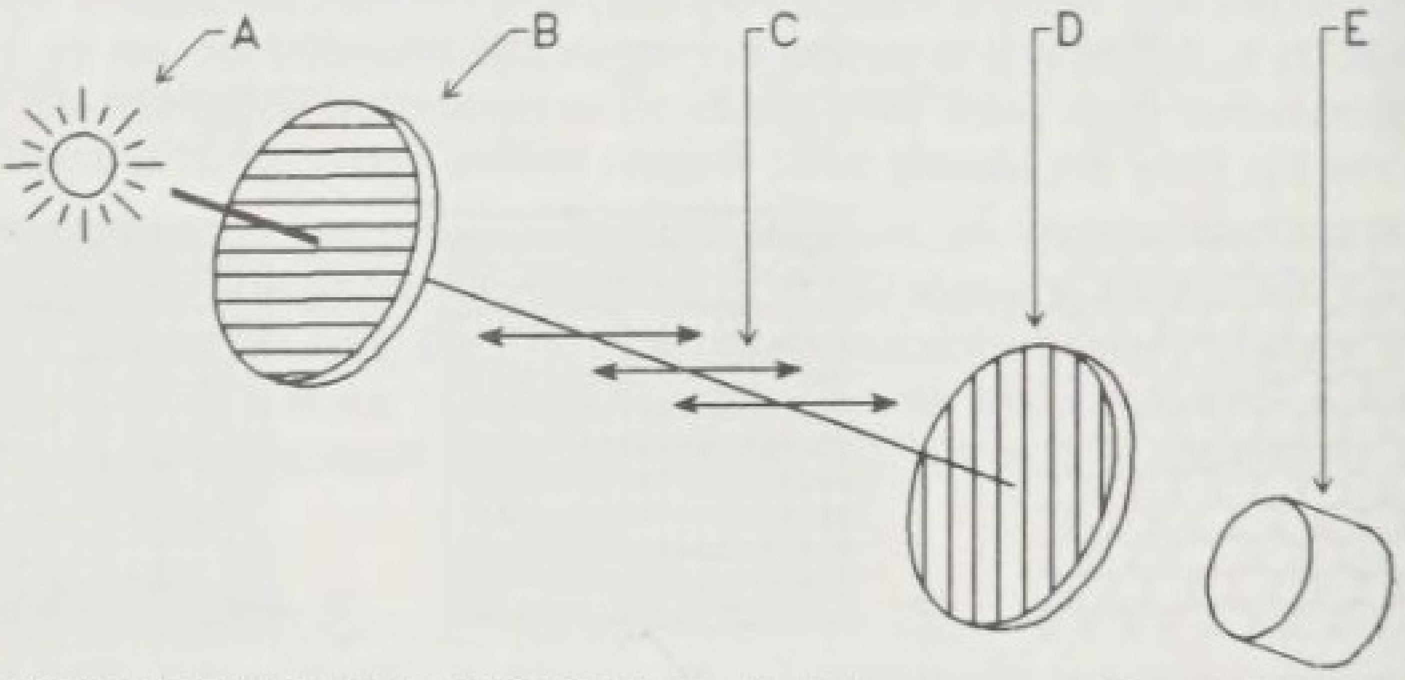
Neutral density filters are used for overall exposure control. They are available either as a neutral gray color or in combination with color conversion filters (85, 85B).

TABLE 1. ND FILTER EXPOSURE FACTORS

Filter	Percentage transmission	Filter factor	Exposure increase (stops)
ND 0.1	80	11/4	1/3
ND 0.2	63	11/2	2/3
ND 0.3	50	2	1
ND 0.4	40	21/2	1 1/3
ND 0.5	32	3	1 2/3
ND 0.6	25	4	2
ND 0.7	20	5	2 1/3
ND 0.8	16	6	2 2/3
ND 0.9	13	8	3
ND 1.0	10	10	3 1/3
ND 2.0	1	100	6 2/3
ND 3.0	0.1	1000	10 1/3
ND 4.0	0.01	10000	13
85N3, 85BN3 etc.	32	3	1 2/3
85N6, 85BN6 etc.	16	6	2 2/3
85N9, 85BN9 etc.	9	11	3 2/3

12.6 POLARIZING FILTERS

Polarizing filters are used for a number of reasons in cinematography and the filters themselves are available in many different types to suit different purposes, many of them outside the realms of cinematography.



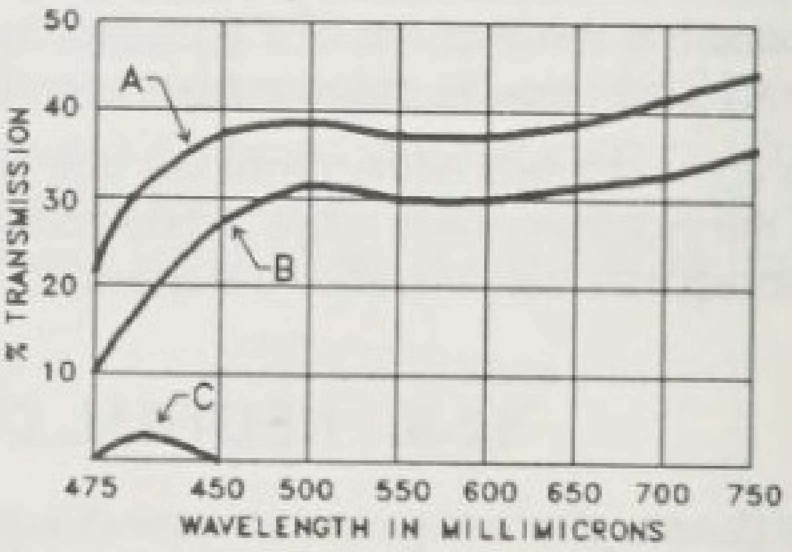
THE EFFECT OF POLARIZING FILTERS, A. Light is generated in all directions. When it encounters a horizontally arrayed polarizer (B) only horizontally polarized light (C) passes through and when this encounters a vertically arrayed polarizer (D) no light passes through to the lens (E).

Polarizing filters need to be set with their plane of polarization at right angles to the direction of polarized light to gain maximum effect. For this reason they must be mounted in a rotatable filter holder to enable the orientation to be maximized. They should not be mounted directly on the front of a lens the front element of which rotates as it is focused.

Polarizers usually have a small index mark on one edge to indicate the direction of polarization.

The linear polarizer most commonly used in cinematography is the Polaroid type HN38 which used singly has a 38% maximum transmission and good extinction capability. Also available is the HN42 with a maximum transmission of 42% but less extinction capability and the HN32 with only 32% transmission but which, when used in combination with a second such polarizer, can reduce transmission down to 0.005%.

See Section 12.5 NEUTRAL DENSITY FILTERS for a TRANSMISSION/ EXPOSURE ADJUSTMENT look-up table.

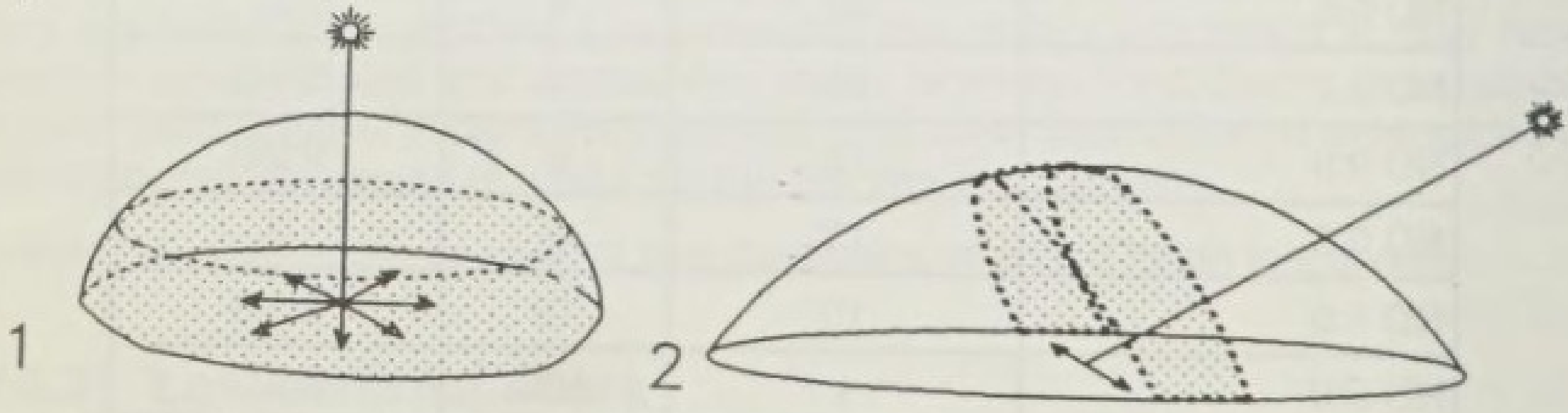


POLAROID POLARIZING FILTER PERFORMANCE GRAPH.

Curve A shows the transmission of a single type HN38 polarizer, B shows the transmission of two polarizers with their axes parallel and C with their axes crossed.

12.6.1 Polarizing filters to reduce glare

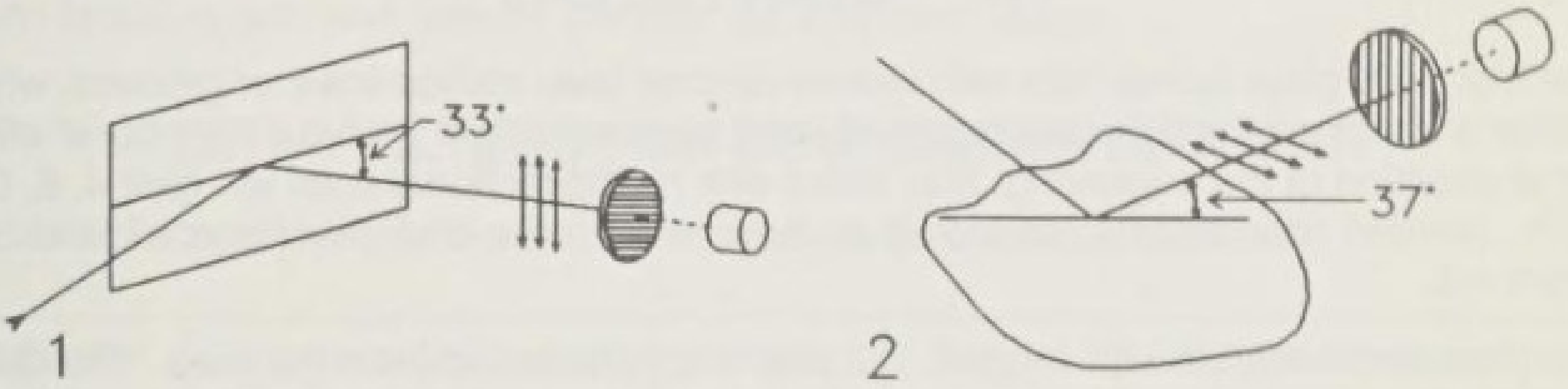
Given the right circumstances polarizing filters can reduce exterior haze and glare, darken blue skies and accentuate cloud formations. For maximum effect the camera should be pointing in a direction 90° to the sun. They have no effect when pointing directly at or away from the sun.



POLARIZING FILTERS USED TO REDUCE GLARE AND DARKEN BLUE SKIES. 1. With the sun directly overhead a polarizing filter will give maximum effect near the horizon in any direction; 2. With the sun at an angle the maximum effect is confined to a band set perpendicular to the direction of the sun.

12.6.2 Polarizing filters to reduce reflections

When light reflects obliquely from a *non-metallic* surface it becomes linearly polarized in a plane parallel to the reflecting surface. The degree to which reflections can be eliminated depends upon the angle of camera to the reflecting surface. With window glass the maximum efficiency occurs at 32° to the reflecting surface and with water it is 37°. The narrower the lens angle the better the overall effect.



THE USE OF POLARIZERS TO CONTROL REFLECTIONS: 1. A single polarizing filter has maximum effect in controlling reflections off windows at an angle of 32° between the glass and the optical axis; 2. Reflections off water can be minimized at an angle of 37°.

12.6.3 Polarizers on both the lights and camera

Complete control of all reflections from all surfaces, including metal, can be achieved by using polarizing filters on both the lighting and the camera.

To be effective care must be taken to ensure that the polarizers on all lamps are orientated in the same direction.

The large sheets of polarizing filter that are available for use on lamps are expensive and should be used with care. They should always be mounted a sufficient distance in front of the lamps and be well ventilated to ensure that they do not get too hot. At temperatures above 175°F (80°C) they rapidly lose their polarizing properties.

Polarizing filters are often used on both the lighting and the camera on animation rostrums to control reflections.

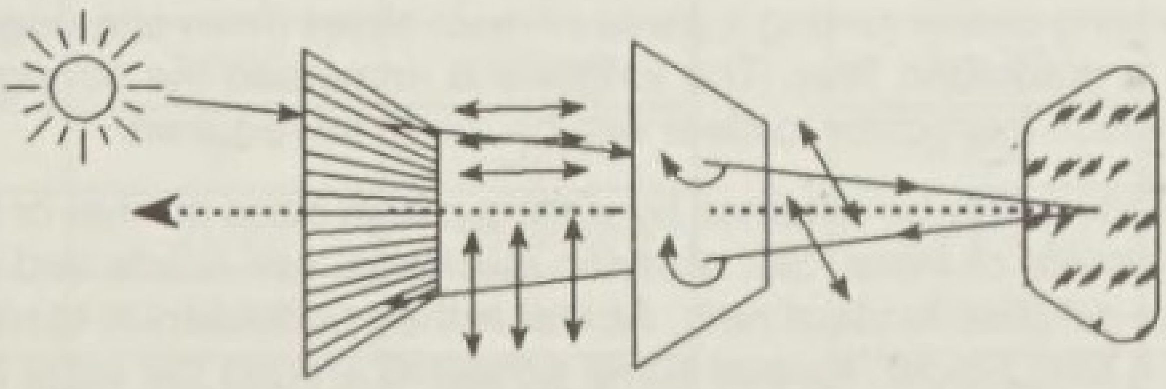
12.6.4 Polarizers as light attenuators

Contra-rotating polarizers can be used to completely control the luminosity of a light source or of the amount of light passing through a lens to the camera without upsetting the color of the light or the optical properties of the lens.

The problems are that 60% of the light is lost in the first place and that the effect is not even as the filters are rotated, becoming more rapid as the polarizers reach their crossed position.

12.6.5 Circular polarizers

Circular polarizers are not camera filters *per se* but nevertheless are very useful tools for the cinematographer. Put simply, circular polarizers allow light to pass through in either direction but will not allow a reflection of light that has already passed through the filter once to repass in the opposite direction.



CIRCULAR POLAROID PLACED IN FRONT OF A VIDEO MONITOR

Circular polarizers are two filters laminated together which work in combination. The first layer, facing the light source to be controlled, is a normal linear polarizer. Behind this is another filter, a 'quarter-wave retardation sheet', set at 45° to the transmission direction of the polarizer, which rotates the polarized light through 45°. Any of that light which is reflected back into the filter (as from the front of a video monitor) is rotated a further 45° in the same direction and then, being 90° out of rotation with the polarizer, is unable to travel further. Direct light from the monitor, meanwhile, passes through unhindered except from the normal loss of transmission which polarizers always cause.

Circular polarizers are mostly used as an aid to viewing video assist monitors in conditions of high ambient light. As a camera tool to make in-shot video monitors look brighter, their effectiveness can be increased by using a polarizing filter on the camera orientated in the same direction as the front of the circular polarizer and controlling the set lighting with polarizing filters set in a semi-crossed direction. See also Section 12.13.2.

12.7 STAR FILTERS

Star filters are glass optical flats with closely spaced laser etched lines, or grooves, which scatter and diffract the light causing small point sources of light to give a 'star-burst' effect in the direction of the engraving. Star filters with multidirectional lines will give 4, 6, 8 or more, pointed star effects according to how many sets and directions of lines are engraved.

Star filters are available with 1/4, 1/2, 1, 2 and 4mm spaces between the lines. The closer the lines the more intense the effect and the wider the spaces between the lines the less degrading effect the filter has on the rest of the scene.

The etching can be left clear or filled with brown or black paint or shoe polish to slightly vary the effect.

12.8 U.V. FILTERS

U.V. filters appear to be clear glass but filter out the ultra violet light below 400nm, which although invisible to the eye photographs on film causing veiling glare and lack of contrast in daylight conditions.

12.9 EXPERIMENTAL FILTERS

For the purpose of experimenting with various effects, cameramen can create many types of effect filter themselves, albeit without the quality, repeatability, durability and control of the professionally made filter.

Float or plate glass is usually acceptably flat for filter purposes although some of it does have an undesirable greenish tone which should be avoided if possible. Glass available for mounting diapositives, slides and transparencies or for picture framing are good sources of thin glass for making laminated filters. It is when two thin sheets of otherwise flat glass are glued together to make a sandwich type filter (to protect the filter surface) that the lack of flatness and parallelism can become a problem. Professionally made filters are often glued together with waterproof adhesive and then ground flat and polished subsequently.

Plexiglass, Perspex or other clear acrylic or resin sheet materials are usually acceptably flat though not as durable as glass. They are also suitable for warming over a flame and bending out of flatness to make distorting filters

Quite a good diffuser can be made by using an aerosol hair lacquer spray. The trick is to spray only very lightly so that each globule remains isolated. Even when it is totally dry you will need to warn anyone else handling such a filter to touch it only by the edges and not to clean it before use. A very light spraying with a fine nozzle using black, white or colored paint can also be interesting.

Rubbing a surface with a kitchen abrasive powder or with a wire wool pad will produce different results again. Acrylic sheet is easier to use than glass for this purpose.

Progressively lowering and/or raising a piece of resin sheet (from one edge) into a bowl of dye can make a graduated filter. The longer it is immersed the stronger will be the color and the transition from color to clear can be made as required.

Silk voile netting can usually be obtained by visiting a high class milliner or by wandering around the back streets of Paris. Silk or nylon stockings, silk scarfs and even fine net curtaining all make different kinds of nets. All that is then necessary is to make up a wire frame the size of a filter holder, spread some adhesive around the edge and apply the netting. Another way is to stretch a piece of net over the back of a lens and hold it in position with 3M ATG-924 'snot tape'.

Star filters can be made to order by the people who make Diffraction Gratings for scientific purposes. They can make multi-star, variable star and graduated star filters as required.

A fine smear of petroleum jelly makes a good diffuser and has the advantage that it can be applied selectively across the picture area. It is useful when a long lens or a wide aperture cannot be used to put a background out of focus.

Making sandwich filters is more difficult. A clear adhesive is required. (Canada Balsam is sometimes used.) The trick is to apply the adhesive evenly and liberally to both surfaces so as to be able to squeeze out all the air bubbles and then let the filter lie between two flat steel plates, and under a centrally placed heavy weight, while the drying takes place. Colored dyes, fine grit and other materials can be mixed in with the adhesive before it is applied to the glass surfaces. Before home-made laminated filters are used they should be tested for optical integrity by eye focusing through a long lens and comparing the result when focusing with and without the filter (or with clear glass).

12.10 FILTERS FOR B&W CINEMATOGRAPHY

In B&W photography filters are used to separate colors of similar tone.

Wratten No.	Exposure factor	Exposure increase	Color	Degree	Daylight effect and use
3	1.5	1/2	Light yellow	Slight	Penetrates aerial haze
8	2	1	Medium yellow	Moderate	Corrects panchromatic color balance
11	4	2	Green 1	Light	Lightens green foliage
12	2	1	Yellow	Strong	Increases contrast
15	2.5	11/4	Deep yellow	Heavy	Lightens faces and darkens blue skies
21	3	11/2	Light orange	Slight	Over correction
23A	5	21/4	Deep orange	Moderate	Heavy haze penetration
25	8	3	Red	Heavy	Whitens faces and blackens skies
29	16	4	Deep red	Extreme	Strong contrasts Dark blue skies Exaggerated clouds

12.11 EXPOSURE FACTORS

Filter factor	1.5	2	3	4	6	8	12	16	24	32
Exposure increase (stops)	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5

12.12 FILTER SIZES

Circular, diameter		
Series 5	1 3/16"	27.6mm
Series 6	1 5/8"	41.3mm
Series 7	2"	50.8mm
Series 8	21/2"	63.5mm
Series 81/2	2 15/16"	74.6mm
Series 9	31/4"	82.6mm
	41/2"	115mm
	51/2"	**138mm**
	6"	152mm

Square / Rectangular	
2 x 2"	50 x 50mm
3 x 3"	76 x 76mm
4 x 4"	102 x 102mm
4 x 5.650"	102 x 143mm
5 x 5"	127 x 127mm
6 x 6"	152 x 152mm
6.6 x 6.6"	167 x 167mm

Filter are known by the sizes shown in bold.

12.13 IMAGE CONTROL ACCESSORIES

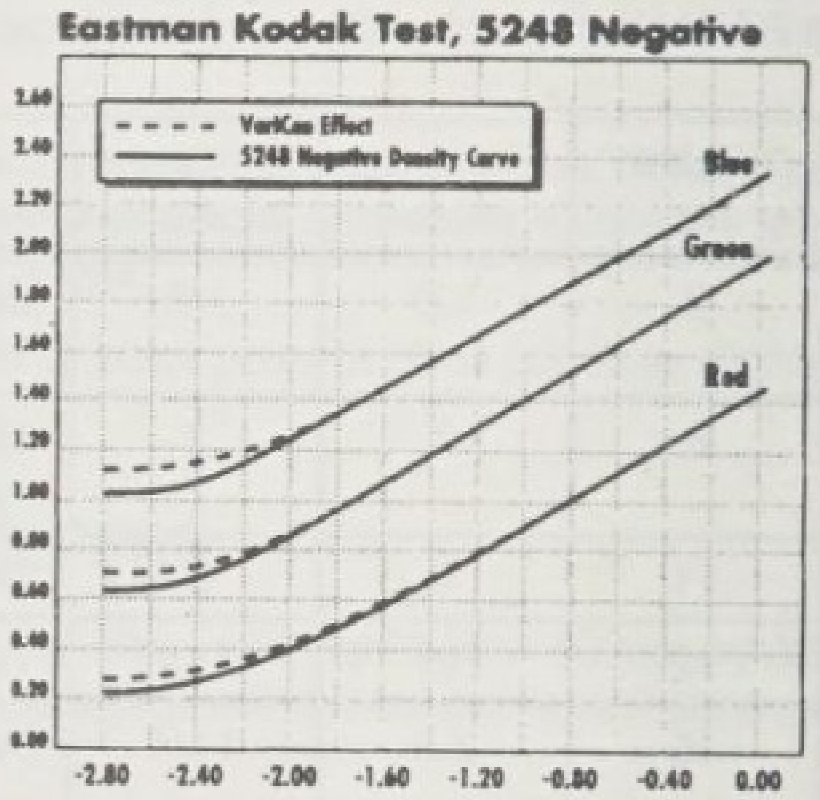
Filters are not the only means to control the photographic image.

12.13.1 Contrast control

Giving a very small, even, overall exposure to the film immediately before, during or after the film is exposed in the camera gate is a method of increasing effective film speed, reducing contrast, putting more information into the shadow areas and, if desired in the case of color film, of tinting the shadows without affecting the highlights. It is a technique as old as photography itself.

Flashing, as it is normally called, introduces a controlled amount of light into the toe of the film's sensitometric curve where normally there is little or no density effect for the first vestiges of shadow information. The amount of light exposed onto the film is extremely small but sufficient to bolster the shadows without affecting the more fully exposed areas of the film. Unlike low contrast filters, which spread highlights into shadows and can cause haloes to appear around sharply defined dark areas, flashing does not affect the overall image sharpness.

The use of flashing is particularly useful when filming dark skin tones and in harsh sunlight conditions where it can bring out detail that would otherwise not photograph.



THE EFFECT OF A VARICON ON THE TOE PORTION OF EASTMANCOLOR 5284 COLOR NEGATIVE

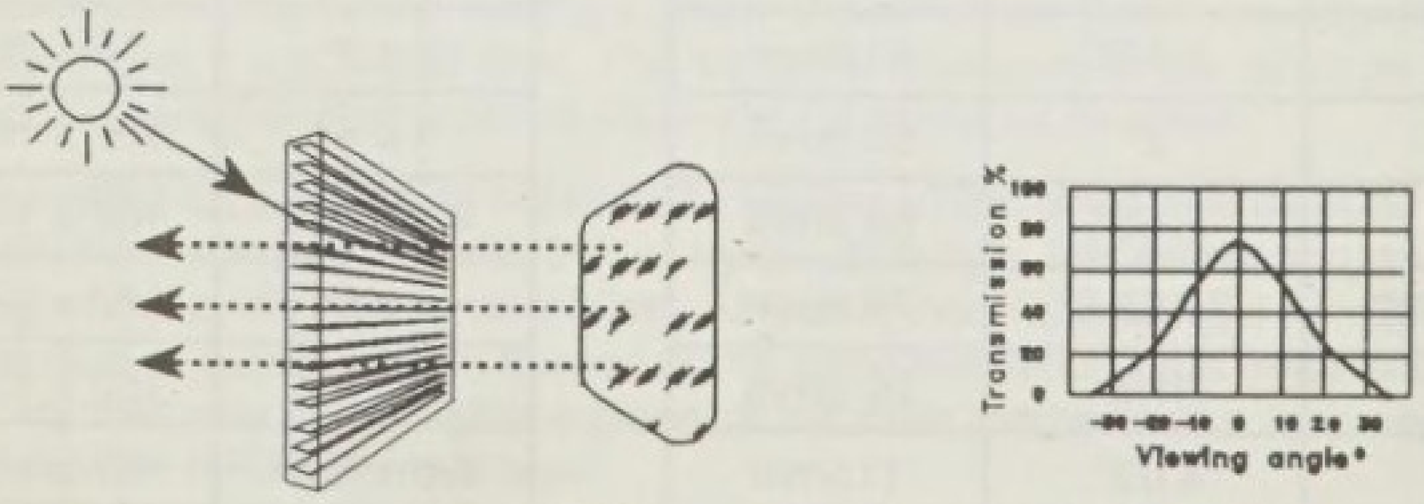
The Arriflex VariCon system was developed from the original Lightflex system which was fitted onto the front of the camera and reflected light through the lens and onto the film. The VariCon unit is like an clear glass filter which fits into the matte box and the edge of which is surrounded by a multitude of small light sources. These edge lights create internal reflections within the glass, some of which reflect back onto the film. The brightness of the light is controlled by a shutter system so that the color temperature of the light remains stable. Color can be introduced if the need is to introduce color into the shadows.

The Panavision Panaflasher unit can be mounted onto either magazine port of a Panaflex camera, whichever one is not being used for the film supply. It makes no difference if the flashing takes place just before or just after exposure in the gate. The brightness of the light of the light system is controlled by an iris and remains free of any color temperature change.

12.13.2 Light control film

Another effective means to make video assist monitors more viewable in bright ambient light conditions is to place a sheet of 3M's Light Control Film (LCF) immediately in front of the screen.

LCF is a thin plastic sheet, only 3/100" (0.76mm) thick, which contains closely spaced microlouvers. It is, in effect, a micro venetian blind which shields out unwanted ambient light. It is as good as having a long hood around the monitor screen.



3M's LIGHT CONTROL FILM PLACED IN FRONT OF A VIDEO MONITOR

Viewed from square-on the light transmission is 75%, at 15° it is 35% and at 30° it is nil. Alternative types permit maximum viewing at a slant angle. Another type has translucent black louvers which permit some viewing up to 50° to the normal.

12.14 LIGHTING and EFFECT FILTERS, etc.

As much as filters are used in front of camera lenses they are also used in front of lamps for a multitude of reasons, some of them technical, others for the sake of art and creativity.

12.14.1 Lighting color correction

The color of the light output can be modified, by subtractive means, to match the requirements of the filmstock, other lighting sources and/or the ambient light.

Amber colored color correction filters (CTO or Color Temperature Orange) are used to convert bluish colored light to match tungsten and other light of lower color temperature.

CTO filter material may be used to cover windows to match the incoming daylight to that of interior tungsten light. Troublesome multiple reflections from in-shot window filters may be cured either by using rigid sheets (which reduce the reflections to one per lamp) or by mounting the filter material onto frames which may be tipped up or down to eliminate all reflections

LIGHTING COLOR CORRECTION FILTERS

FILTER	APPROXIMATE MIRED VALUE	TYPICAL USE
Full CTO	+159	Converts daylight to a nominal 3200˚K
3/4 CTO	+124	Converts daylight to a nominal 3600˚K
1/2 CTO	+109	Converts daylight to a nominal 3800˚K
1/4 CTO	+64	Convert daylight to a nominal 4600˚K
1/8 CTO	+26	Converts 6550˚K daylight to 5500˚K

Blue colored (CTB) color conversion filters raise the color temperature of a tungsten light source to match that of daylight.

FILTER	APPROXIMATE MIRED VALUE	TYPICAL USE
Double CTB	-274	Changes 3200˚K tungsten light to 20000˚K daylight
Full CTB	-137	Changes 3200˚K tungsten light to photographic daylight
3/4 CTB	-112	Changes 3200˚K tungsten light to 5000˚K daylight
1/2 CTB	-78	Changes 3200˚K tungsten light to 4300˚K daylight
1/4 CTB	-35	Changes 3200˚K tungsten light to 3600˚K daylight
1/8 CTB	-18	Changes 3200˚K tungsten light to 3400˚K daylight

Note: MIRED values vary considerably between different manufacturers. They may also vary between different batches and with age, exposure to heat and exposure to light.

Filters may be stacked for greater effect, the MIRED values becoming accumulative.

Special filters with discrete colors are available for controlling carbon arc, HMI and UV light.

If the filmstock itself does not incorporate a fluorescent light correction filter a 'plus' green lighting filter may be used to impart a green cast over tungsten or metal halide lighting (in which case a fluorescent filter is used on the camera) or, conversely, a 'minus' green (magenta) filter may be used on individual fluorescent lights to match them to other lighting.

As with CTO filters, ND filter material may be used to cover windows to reduce the amount of incoming light. Alternatively, scrim, which has a minimum of reflection problems, can be used for the same purpose.

See Section 14.4 for more information.

12.14.2 Diffusion

The characteristics of the shadows created by a lamp can be altered. Hard light can be softened to give diffuse shadows or turned into totally shadowless lighting. To a limited extent, it is also possible to slightly harden otherwise soft shadows.

12.14.3 Heat control

Filters that are colorless to the visible spectrum but which absorb infra-red light can be used to protect heat sensitive areas, including other lighting filters, that may deteriorate in high thermal conditions.

12.14.4 Neutral density filters

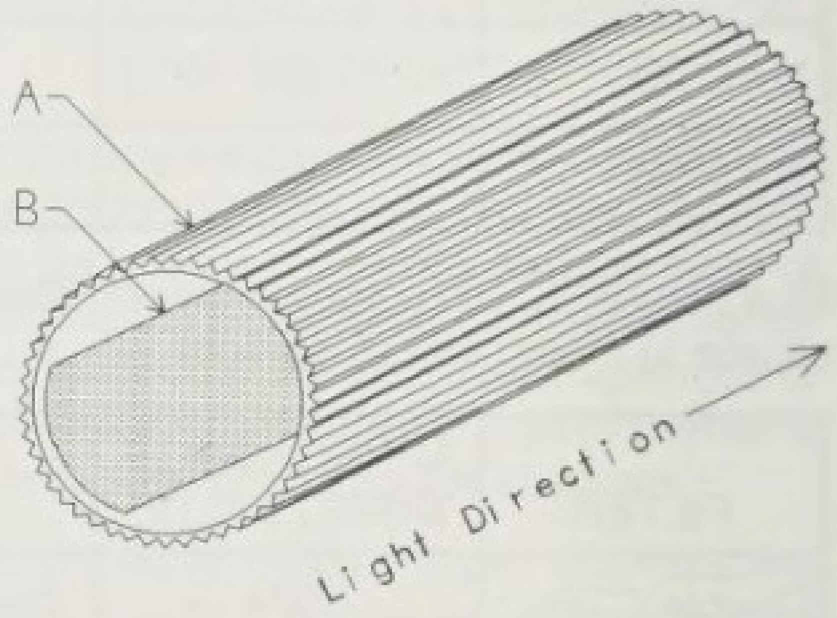
Neutral density filters can be used to reduce the amount of light coming in through a window. They are also available in combination with a CTO filter. (See Section 12.5).

12.14.5 Opaque foil

Thickish opaque foil material, with a matte black or white surface, that can be bent, moulded and mounted is available to control and manipulate light.

12.14.6 Optical lighting film

3M's Scotch Optical Lighting Film may be used to transport and distribute light a considerable distance away from it's source. A transparent material with rows of tiny parallel prisms on one side and a smooth surface on the other, it may be formed into a tube (with the prisms on the outside) through which light can be channelled as a parallel beam, bouncing from side to side within the tube as it travels. Tubes can be mitered together to turn corners. If a strip of reflector material is placed along the inside length of the tube it will act as an 'extractor' and create a strip or column of light. Optical Lighting Film with smaller grooves may be used as a light enhancing material.



LIGHT PIPE: A. Optical Lighting Film;
B. Light 'Extractor'

12.14.7 Polarizing filters

Polarizing filters on the lights can be used in combination with a polarizing filter on the camera to control unwanted hi-lights and reflections. (See Section 12.6.3.)

12.14.8 Reflector material

Silver, silver/gold, gold and white colored reflector materials are available for surfacing reflector boards. They vary from a hard mirror to diffuser soft in effect. If a reflector is too bright a scrim can be put over it to reduce its effect.

12.14.9 Smoke and fog

Smoke and fog are frequently used to diffuse the visual look of a scene. Fog may be anything from a wisp of cigarette smoke to the interior of a storm cloud. It may be low-lying to all embracing.

Low-lying fog is created by pouring hot water over dry ice and blowing or fanning it to where it is required. General fog is created by vaporizing a special liquid and blowing it onto the set as required.

13 LENS INFORMATION

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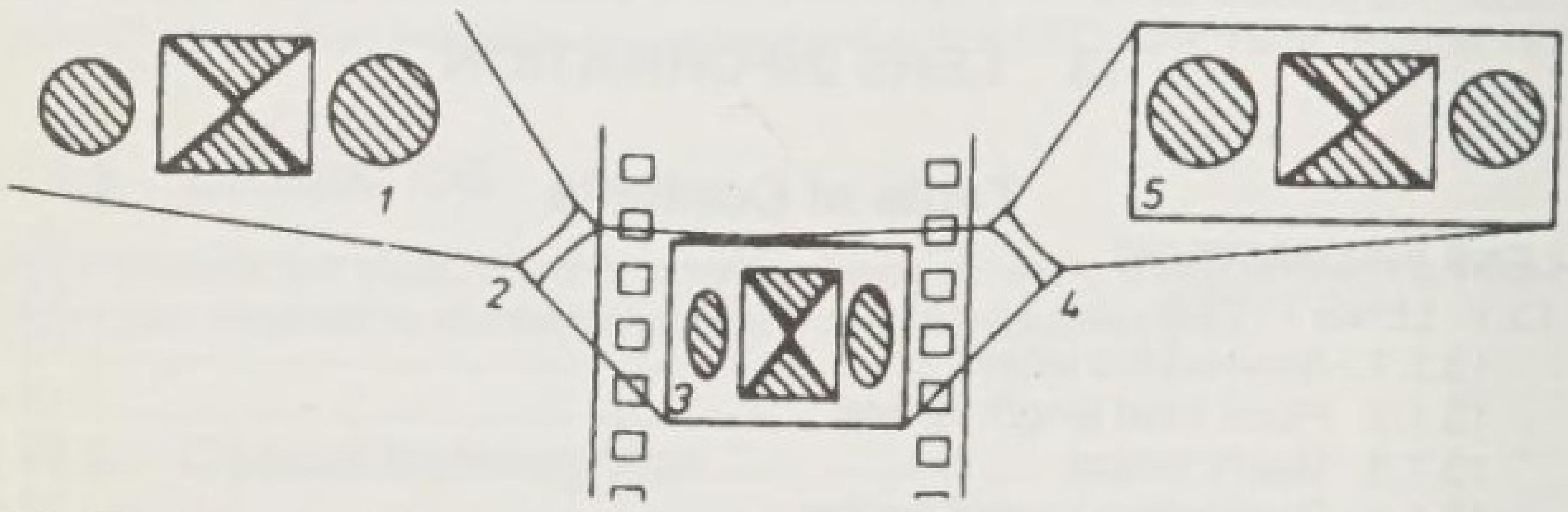
Everything we photograph must pass through the lens so we had better make good choices in the first place and then set lenses correctly when we use them.

The added values that can be given to the imagery of a motion picture by the choice of lenses, making use of the many special purpose lenses that are available, is boundless.

13.1 LENS TYPES

13.1.1 Anamorphic lenses

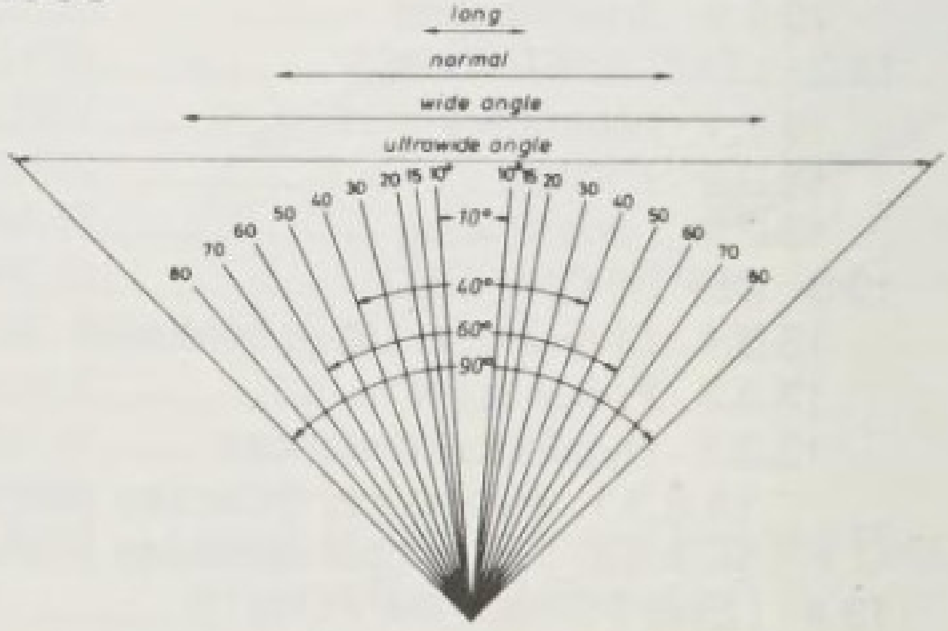
'Anamorphic' or 'Scope' lenses incorporate an optical element which squeezes the image by 50% in the horizontal direction thus enabling an image twice as wide as normal to be photographed onto a standard width film. A complementary lens, which stretches the image, is used for projection thus enabling a wide screen format to result.



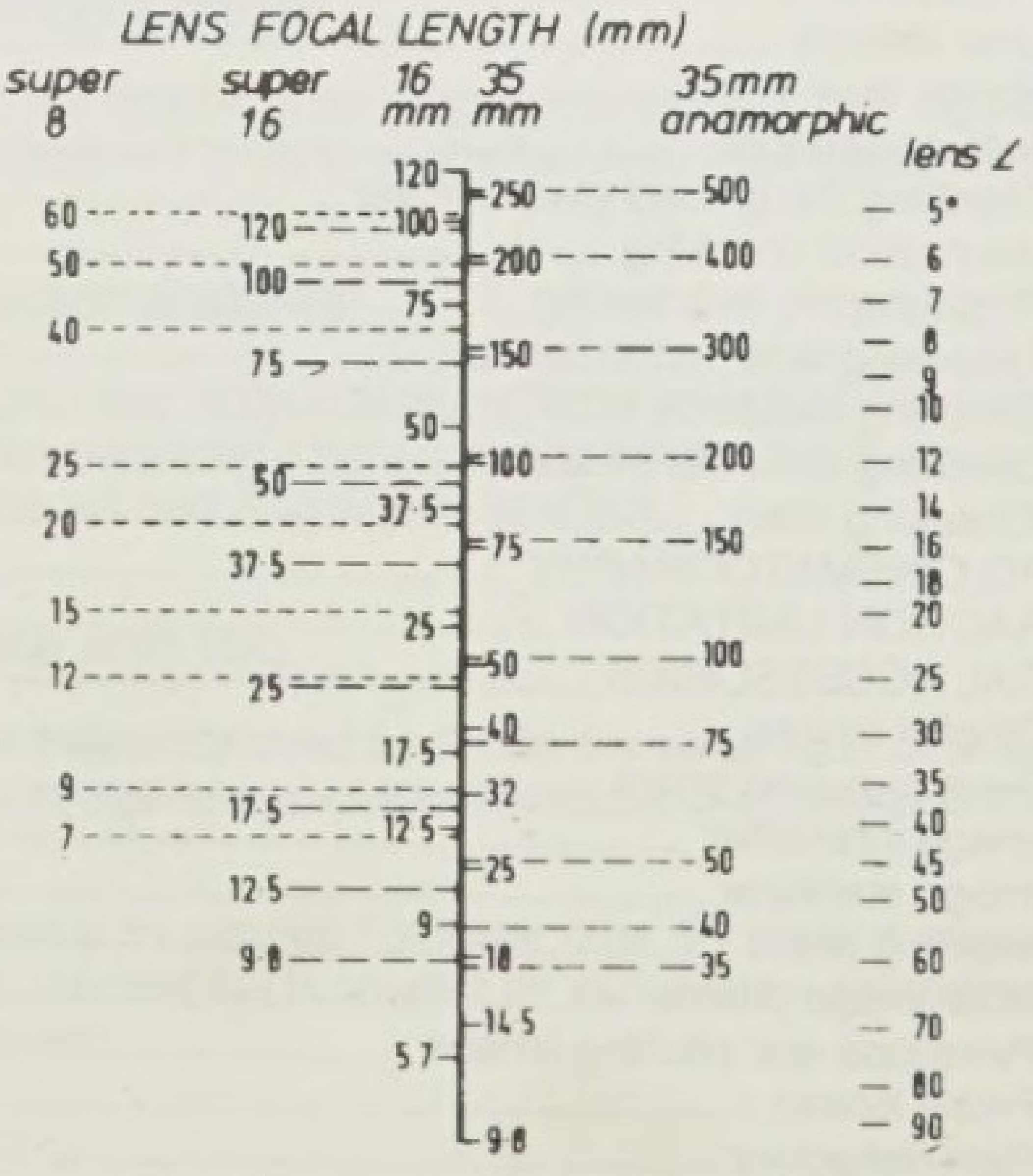
ANAMORPHOSIS: 1. Original scene, 2. Anamorphic camera lens, 3. Anamorphic image with 2:1 squeeze, 4. Anamorphic projection lens, 5. Projected image.

13.1.2 Fixed focal length lenses

'Normal' fixed focus lenses range from about 25 to 100mm for the 35mm format and 12.5 to 100mm for 16mm and have an aperture of about f/2 to f/2.8. Longer lenses are usually of the telephoto type to reduce their physical size. Wider angle lenses are usually of the inverted telephoto type to give extended back focal distance to make room for the shutter and the reflex mirror fitted to motion picture cameras.



LENS ANGLES



LENS FOCAL LENGTH/LENS ANGLES

LENS ANGLE/FOCAL LENGTH LOOK-UP TABLES

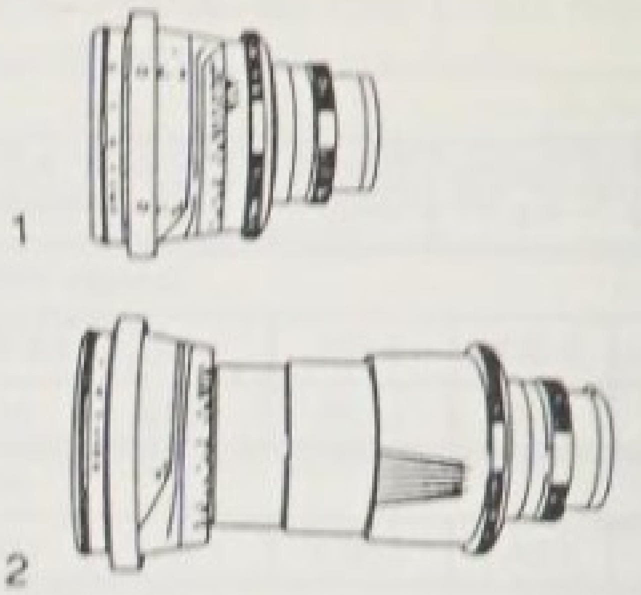
	FORMAT								
	STANDRD 16	SUPER 16	ACADMY	FULL FRAME	ANA-MORPHIC	VISTA-VISION	65mm	1/2" VIDEO	2/3" VIDEO
	IMAGE WIDTH (Projector aperture)								
Inches	0.378	0.463	0.825	0.945	0.838	1.418	1.913	0.5	0.667
mm	9.6	11.76	20.96	24.0	21.29	36.01	48.59	12.7	16.93
	ASPECT RATIO								
	1.33:1	1.66:1	1.37:1	1.33:1	2.35:1	1.5:1	2.2:1	1.33:1	1.33:1
LENS FOCAL LENGTH (mm)	HORIZONTAL LENS ANGLE (°)								
400	1.4	1.7	3	3.4	6.1	5.2	7	1.8	2.4
250	2.2	2.7	4.8	5.5	9.8	8.2	11	2.9	3.9
200	2.7	3.4	6	6.9	12	10	14	3.6	4.8
150	3.7	4.5	8	9.1	16	14	18	4.8	6.5
135	4.1	5	8.9	10.2	18	15	20	5.4	7.2
100	5.5	6.7	12	14	24	20	27	7.3	9.7
85	6.5	7.9	14	16	29	24	32	8.5	11
75	7.3	9	16	18	32	27	36	10	13
50	11	13	24	27	48	40	52	14	19
40	14	17	29	33	60	48	63	18	24
35	16	19	33	38	68	54	70	21	27
30	18	22	39	44	78	62	78	24	32
27	20	25	42	48	86	67	84	26	35
25	22	26	45	51	92	72	88	29	37
20	27	33	55	62	112	84	101	35	46
17	32	38	63	70	128	93	110	41	53
14.5	37	44	72	79	145	102	118	47	61
10	51	61	93	100	187	122	135	65	80
LENS ANGLE (°)	LENS FOCAL LENGTH (mm)								
1	550	674	1201	1375	2440	2063	2784	728	970
1.5	367	449	801	917	1626	1375	1856	485	647
2	275	337	600	687	1220	1032	1392	364	485
3	183	225	400	458	813	688	928	242	323
4	137	168	300	344	610	516	696	182	242
5	110	135	240	275	488	412	556	145	194
7	78	96	171	196	348	294	397	104	138
10	55	67	120	137	243	206	278	73	97
15	36	45	80	91	162	137	185	48	64
20	27	33	59	68	121	102	138	36	48
25	22	27	47	54	96	81	110	29	38
30	18	22	39	45	79	67	91	24	32
40	13	16	29	33	58	49	67	17	23
50	10	13	22	26	46	39	52	14	18
60	8	10	18	21	37	31	42	11	15
80	6	7	12	14	25	21	29	8	10
100	4	5	9	10	18	15	20	5	7

Notes: Given the film format and the horizontal lens angle the upper part of the table shows LENS FOCAL LENGTH. Given the lens focal length the lower part shows the HORIZONTAL LENS ANGLE.

To calculate the VERTICAL LENS ANGLE divide the horizontal lens angle by the first part of the aspect ratio (above).

13.1.3 Macro lenses

'Macro' lenses are optically corrected and specially mounted lenses, with additional extension, to enable them to be focused at short distances to give a magnification ratio greater than 1:1. Some newer long focal length lenses have internal focusing capability to enable them to enlarge an object much like a microscope. See Sections 13.6, 13.7 and 15.6.7 for more information.

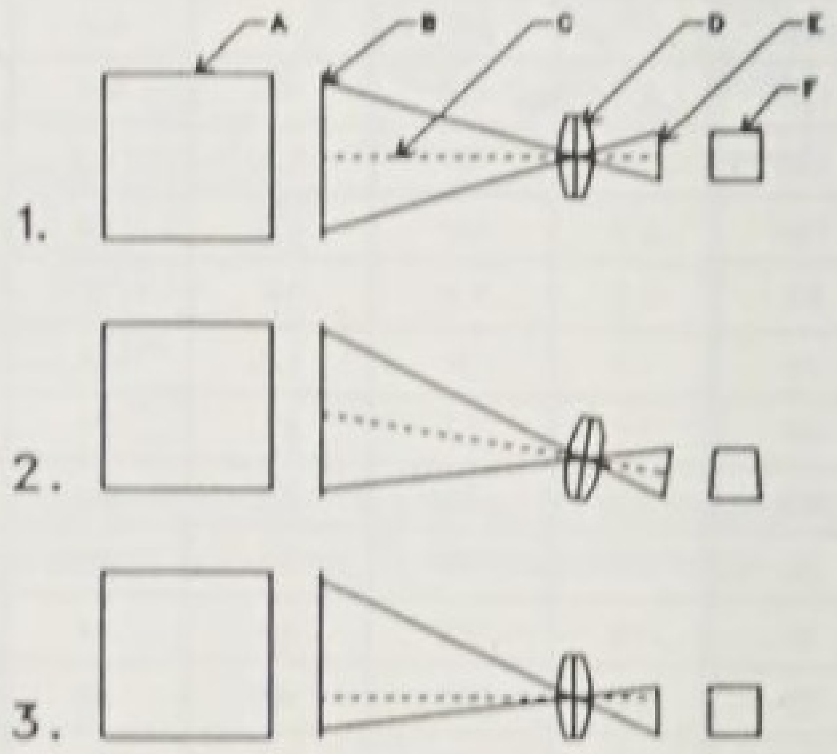


TYPICAL TRIPLE EXTENSION MACRO LENS: 1. Focused on infinity; 2. Focused down to 1:1.

13.1.4 Perspective control lenses

'Perspective control' lenses have lens mountings which enable the optical unit to be slid in any direction across the optical plane (up, down or sideways) while still keeping the optical axis square to the image plane. This movement, or 'translation' as it is correctly called, makes it possible to simulate a 'square-on' image. It is usually used in a vertical mode to avoid the 'falling over backwards' look of buildings when photographed with a tilted-up camera or horizontally to create a square-on look when a square-on camera position is not possible.

A lens used in this type of mounting needs to be wide angle enough to be useful but must also have extra coverage with good image definition and brightness characteristics in the corners of the image area to allow for the optical displacement. Best used with a moderate aperture.



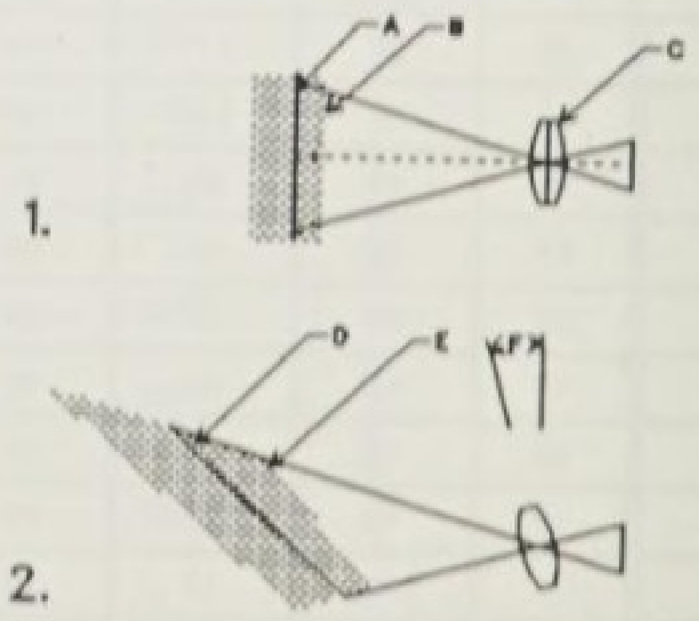
PERSPECTIVE CONTROL

1. CAMERA SET SQUARE TO THE OBJECT: A. Shape of original object, B. Image plane, C. Optical axis, D. Lens, E. Image plane, F. Shape of image; 2. CAMERA TILTED UPWARDS OR SIDEWAYS, A square object results in a trapezoid shape image; 3. Optical axis displacement results in an image with parallel sides.

13.1.5 Slant focus lenses

'Slant focus' lenses are lenses which can be rotated about the optical axis to enable the plane of focus to be set further away from the camera on one side than on the other. The effect is like that of a split diopter but without the hard dividing line. Used in conditions of minimal depth of field to photograph a subject set at an angle to the camera i.e., when shooting a 3/4 side-on shot of a group of people in low light conditions. Particularly useful for 70mm and anamorphic cinematography.

The Panavision bellowless Slant Focus Lens has a special lens mounting which permits the lens to be rotated accurately about the rear exit pupil and has facilities to both 'pull focus and 'pull slant' in shot.



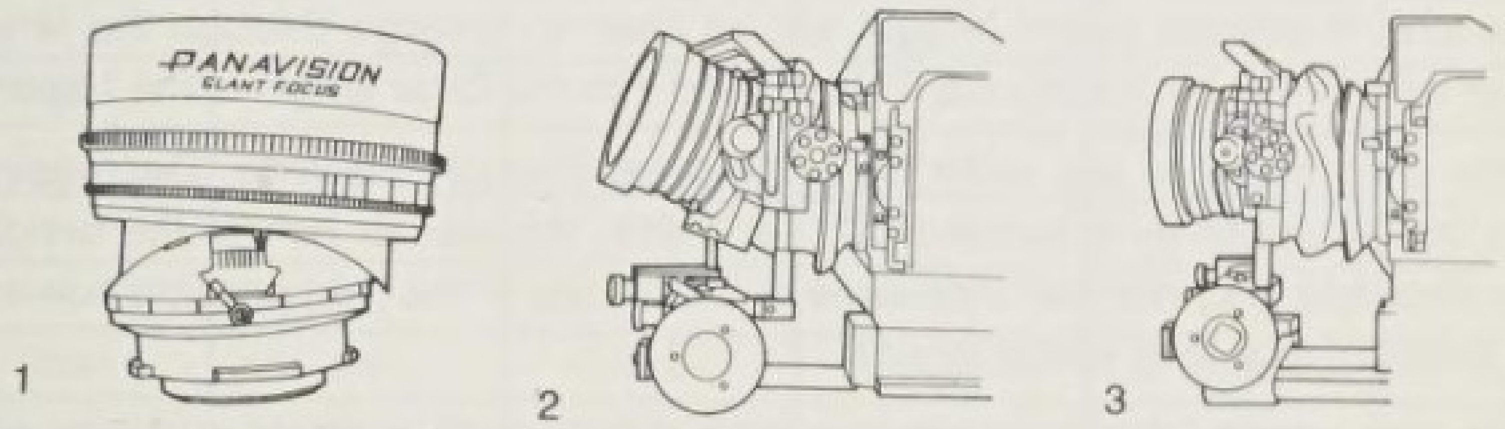
1. NORMAL FOCUS: A. Normal plane of focus square to the optical axis; B. Normal depth of field zone, C. Lens set parallel to the focal plane; 2.SLANT FOCUS: D. Subject set obliquely to the normal plane of focus, E. Oblique focus zone. F. Lens rotated.

13.1.6 View camera lens mounting systems

Similar to the panel lens mounting systems found on large plate cameras. Lenses can be mounted independently of the camera with a lightproof bellows between the two. A panel type lens mounting with a bellows camera interface offers the following facilities:

- Normal focusing with macro capability.
- Rise and fall front to position an object and to correct verticals.
- Cross front to position an object and to minimize a vanishing point
- Tilt and swing to position the depth of field zone.
- Ease of mounting non-standard lenses.

Especially useful for macro and special effects work where no in-shot focus adjustment and camera movements are necessary.



SPECIAL LENS MOUNTINGS: 1. Slant focus lens; 2. View camera lens mounting system; 3. Rise and fall used for perspective control

13.1.7 Wide aperture lenses

Usually about one or two stops faster than a normal lens of a similar focal length. Are useful in low light conditions and when it is desirable to limit the depth of field. Usually they do not provide as much contrast or image sharpness as a normal aperture lens.

13.1.8 Wide angle lenses

Short focal length lenses used where it is necessary to include more subject matter than is possible with a normal lens within the focal distance available or when it is desirable to distort perspective. Modern, high quality wide angle lenses are virtually distortion free.

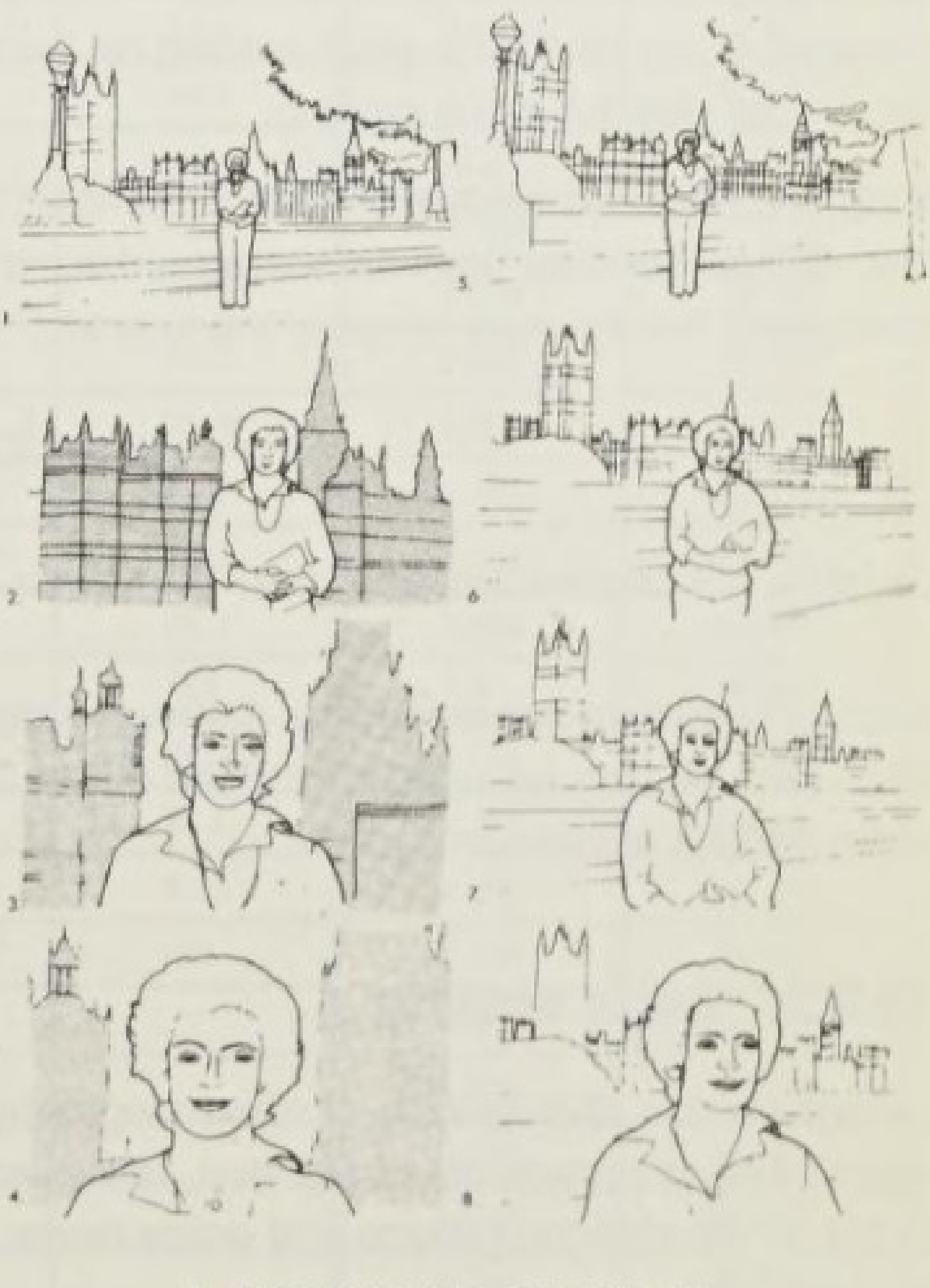
13.1.9 Zoom lenses

'Zoom' lenses are lenses which have the facility for the focal length to be changed without affecting either the aperture setting or the focus.

The 'in-shot' effect of a zoom is very different to that of dollying a camera. In the case of a dolly shot, a foreground object will be enlarged as the camera goes in closer while a distant background will remain substantially the same. In the case of a zoom-in shot, not only will a foreground object be enlarged but background will close in from the sides and it too will be enlarged.

Optically, the latest generation of zoom lenses match any fixed focus lenses in terms of resolving power, contrast, freedom from distortion and veiling glare, etc.

On the down side most zoom lenses have less depth of field at close distances than fixed focal length lenses (due to their physical length) and have a limited full aperture and close focusing capability.



1. DOLLY-IN; 2. ZOOM-IN
Note the difference in the background images.

13.2 LENS APERTURES

13.2.1 f-Numbers

The f-number of a lens is a physical measurement of the theoretical ability of a lens to pass light and is obtained by dividing the focal length of the lens by the maximum diameter of a beam of light which will pass through a lens about the optical axis (f=*F/d* where *F*=focal length, *d*=diameter). Thus a 100mm focal length lens which will pass a beam of light 50mm wide at full aperture is said to be 'f/2'.

A simple way to measure the f-number of a lens is to set the lens up with a pinhole at the focal plane (the point of focus), with a small light source behind it, and with the lens set to full aperture. A parallel beam of light will be seen to emerge through the lens the diameter of which may be measured. This divided into the focal length is the f-aperture.

The smaller the f-number the more light will pass through the lens. Decreasing or increasing the f-number by a factor of $\sqrt{2}$, i.e. 1.414, doubles or halves the exposure. Halving or doubling the f-number increases or decreases in the light passing power of a lens by a factor of four (two whole stops).

For camera lens usage f-numbers are invariably rounded off to whole numbers or one decimal point.

Hyperfocal Distances and depth of field calculations etc. are always relative to the f-aperture of a lens, not the T stop.

13.2.2 T stops

The T stop of a particular lens is a measurement of the actual amount of light it will pass after allowing for transmission losses due to absorption, internal reflections, scattering, etc.

Exposure settings on a lens for given situation must always be made relative to T stops which is a measure of the actual light passing efficiency of a lens and makes possible lens interchangeability while maintaining exposure consistency.

For practical purposes T stops of lenses may most easily be checked by making comparisons between a number of other lenses. A piece of translucent material, illuminated from behind, is placed in the focal plane of a lens. The intensity of light projected through the lens is measured along the optical axis with an incident light meter. If one lens requires to be set at say f/5.6 for a given reading on the photometer, then any other lens similarly set should give the same reading.

T stops are always smaller (higher in number) than f-apertures, i.e. f/5.6 may equal T6. The differential may also be expressed as a percentage and will remain consistent throughout the aperture range of the lens viz:

$$T = \frac{f}{\sqrt{(normalized transmission)}}$$

i.e., if f = 1.8 and the transmission = 81% then $T = \frac{1.8}{\sqrt{0.81}} = \frac{1.8}{0.9} = T2$

In order to ensure consistency of aperture setting it is standard practice always to set a lens aperture from full open to stopped down. It is particularly important to do it this way when making adjustments at the f/11-16-22 end of the scale.

13.2.3 Lens scaling

Lenses used in photography or cinematography are normally scaled to an accuracy of 2 figures and in increments of 1/3 stop. However, some older exposure meters measure in 1/4 or 1/2 stop increments and some newer ones show digital readings in 1/10 stop divisions viz:

INTERMEDIATE STOPS LOOK-UP TABLE

Whole stops	Half stops	Third stops	Quarter stops	One tenth stops	
				f/1 - 5.6	f/5.6 - 32
1	**1**	**1**	**1**	**1**	**5.656**
	1.19	1.12	1.09	1.035	5.856
		1.26	1.19	1.072	6.063
			1.3	1.110	6.277
1.4	**1.41**	**1.41**	**1.41**	1.149	6.498
	1.7	1.58	1.55	1.189	6.727
		1.77	1.69	1.231	6.964
			1.84	1.275	7.210
2	**2**	**2**	**2**	1.319	7.464
	2.38	2.24	2.18	1.366	7.727
		2.51	2.38	**1.414**	**8**
			2.6	1.464	8.282
2.8	**2.8**	**2.82**	**2.84**	1.516	8.574
	3.3	3.17	3.1	1.569	8.876
		3.56	3.38	1.625	9.190
			3.69	1.682	9.514
4	**4**	**4**	**4**	1.741	9.849
	4.8	4.5	4.36	1.803	10.196
		5.1	4.75	1.867	10.556
			5.18	1.932	10.928
5.7	**5.7**	**5.7**	**5.65**	**2**	**11.314**
	6.8	6.4	6.16	2.071	11.713
		7.2	6.72	2.144	12.126
			7.33	2.219	12.553
8	**8**	**8**	**8**	2.297	12.996
	9.5	9	8.7	2.378	13.454
		10.1	9.5	2.462	13.929
			10.4	2.549	14.420
11.3	**11.3**	**11.3**	**11.3**	2.639	14.929
	13.4	12.7	12.3	2.732	15.455
		14.3	13.4	**2.828**	**16**
			14.6	2.928	16.564
16	**16**	**16**	**16**	3.031	17.148
	19	18	17.4	3.138	17.753
		20.2	19	3.249	18.379
			20.7	3.636	19.027
22.6	**22.6**	**22.7**	**22.6**	3.482	19.698
	27	25.5	24.6	3.605	20.393
		28.6	26.8	3.732	21.112
			29.2	3.864	21.857
32	**32**	**32**	**32**	**4**	**22.627**
	38	35.9	34.9	4.141	23.425
		40.3	38.1	4.287	24.251
			41.5	4.438	25.107
45	**45**	**45**	**45**	4.595	25.992
				4.757	26.909
				4.925	27.858
				5.098	28.840
				5.278	29.857
				5.464	30.910
				5.656	**32**

13.3 DEPTH OF FIELD

The Depth of Field of a lens is the distance in front of and behind the point of focus which, when viewed on the screen, can be considered to be acceptably in-focus or sharp.

In cinematographic practice this very often means selecting the near and far distances which need to be held equally and acceptably in-focus and setting the focus distance to suit, i.e., a FOCUS SPLIT.

What is the acceptable depth of field in any particular situation may be influenced by the following:

- The maximum definition of a lens by comparison with which anything slightly out of focus will appear to be exaggerated
- Lighting which accentuates sharply focused detail. Brightly lit objects will appear to have less depth of field
- The presence in the scene of something brightly lit which draws attention to an in-focus or out-of-focus element
- Excessive magnification difference between near and far distances. Use of wide angle lenses at close focusing distances will cause distant objects (which are very much smaller than near objects) to have less depth of field
- The use of diffusion filters or nets, star filter, fog filter, fog or smoke in between the lens and the subject etc. which will reduce maximum definition and make a greater degree of soft focus acceptable
- The degree of magnification that the image may be subjected to when shown and the closeness of the audience to the screen (i.e. an audience sitting close to a large cinema screen will be more aware of soft focus when those sitting far away from a small T.V. screen)
- The ability of the presentation system to resolve fine detail (a good projector lens and a well-illuminated 70mm print at one end of the scale, a badly adjusted T.V. receiver at the other

In the real world of cinematography the practice of setting focus according to the nearest and further objects that need to be held in acceptable focus is further refined by allowing for a controlled amount of FOCUS BIAS one way or the other. This can be quite subtle and can occur when one artist is more important or more expensive than another, when one artist is talking and the other is listening or when there is more light on one artist and less on the other.

Depth of field is dependent upon the following factors:

- The focal length of the lens (the longer the focal length the less the depth of field),
- The aperture (the wider the aperture the less the depth of field),
- The circle of confusion (the diameter, on film, of the out-of-focus image created from an infinitely small spot of light),
- The design and construction of the lens and the position of the front nodal point of the lens relative to the film plane.

In cinematography, focus is always measured from the focal plane yet depth of field is calculated from the front nodal point position. In most cases (but not always) the front nodal point is closer to the subject than the focal plane. This means that a lens that has its front nodal point well forward of the focal plane will have less depth of field than might be expected while one where the pupil is far behind the focal plane might have more.

While with most fixed focal length lenses this does not make much difference, with physically long zoom lenses the difference can be quite considerable, especially at the wide angle end of the zoom range. An arbitrary 2" (50mm) has been allowed on the depth of field tables at the end of this section and while this may not be enough in some cases, in others, where the front nodal point may be behind the focal plane, it may be too much. While the tables are probably not absolutely accurate for any one particular lens they do indicate a good average and are likely to be closer to reality than tables that have no front nodal point compensation.

All lenses, especially zoom lenses, do vary and may have more or less depth of field on either side of the plane of focus than might be expected. Users should either make comprehensive depth of field tests before shooting commences or observe dailies critically always bearing this possibility in mind.

13.3.1 Choice of circle of confusion

Cameramen should be selective in chosing the depth of field they work to, using 1/500 or 0.002 inch (0.05mm) or more when the circumstances are easy, 1/1000 or 0.001 inch (0.025mm) as a middle-of-the-road value and 1/2000 or 0.0005 (0.0125mm), or even less, when tolerances need to be tight. The correct circles of confusion to work to can only be determined by looking at dailies (rushes) on the screen and noting focus splits shot under similar circumstances. If they appear to be too tight then it would be advisable to calculate depth of field and focus splits using a smaller circle of confusion, if they are loose then it may be possible to use a larger circle of confusion.

It should also be noted that is rarely worth calculating the depth of field of very long focal length lenses or of regular lenses at very close focusing distances and at very wide apertures as there is so little latitude under these circumstances that it is hardly worth bothering about.

13.3.2 Focus splits

The common way to look at depth of field is to start with the knowledge that the lens focal length is 'x', the aperture is 'y' and the point of focus is 'z', etc., and then to ask what are the near and far distances?

In practice, however, depth of field very often has to be looked at in reverse. The problem that presents itself is that for a particular set-up one person or object is at 'x' distance from the camera and another is at 'y' distance and if they are both to be equally sharp (or unsharp?) where should the focus be set and given the lens aperture what is the maximum lens focal length or, given the lens focal length, what is the minimum aperture to hold that split?

Alternatively, if both the aperture and the lens focal length are known then given the furthest distance what is the distance to focus on and what is the nearest distance or, given the near distance, what is the distance to focus on and what is the far distance?

These are all called a 'Focus Splits' and are the manner in which 'Depth of Field' is invariably applied in the real world of cinematography.

See Section 15.6.4 for more FOCUS SPLIT information and formulae and Section 13.8 for DEPTH OF FIELD/FOCUS SPLIT tables.

13.3.3 Hyperfocal distances

The hyperfocal distance is the distance in which a lens must be focused so that objects both at infinity and at the nearest possible distance to the camera are in the same acceptably sharp focus.

The hyperfocal distance depends upon the focal length of the lens, the aperture and the diameter of the circle of confusion selected.

When a lens is set to the hyperfocal distance objects from half that distance to infinity will not exceed the degree of out-of-focus that can be tolerated.

Opening the lens aperture by two stops makes the hyperfocal distance twice as far away from the lens and stopping down two stops makes it half the distance away.

A rule-of-thumb way to estimate the hyperfocal distance is to remember the f/1 hyperfocal distance for a given focal length lens and from this it is possible to mentally calculate the hyperfocal distance for any aperture simply by dividing the f/1 distance by the aperture to be used.

For instance, if a cinematographer remembers the figure 320 (or 96 in meters) in relation to a 50mm lens it is then just a matter of dividing that number by 4 to find the hyperfocal distance for that lens at f/4 (80ft or 24m), by 8 to find the hyperfocal distance at f/8, and so on. If the 50mm lens at f/4 is then set to 80ft (24m), everything between 40ft (12m) and infinity will be acceptably sharp.

See Section 15.6.3.2 for hyperfocal distance formulae.

HYPERFOCAL DISTANCE LOOK-UP TABLES

To determine the hyperfocal distance for a particular set of circumstances first select the c. of c. that is considered adequate, follow along that line to select the aperture and then go down the column to select the lens focal length and hyperfocal distances. For instance, with a c. of c. of 1/1000 (0.001) in., at f/8, the hyperfocal distance for a 50mm lens is 40 ft.

13.3.3.1 Hyperfocal distances (feet)

Circle of Confusion (ins.)		Aperture													
1/500	0.002					1	1.4	2	2.8	4	5.6	8	11	16	22
1/710	0.0014				1	1.4	2	2.8	4	5.6	8	11	16	22	
1/1000	0.001			1	1.4	2	2.8	4	5.6	8	11	16	22		
1/1400	0.0007		1	1.4	2	2.8	4	5.6	8	11	16	22			
1/2000	0.0005	1	1.4	2	2.8	4	5.6	8	11	16	22				
Lens focal length (mm)		Hyperfocal distance (feet)													
250		16146	11533	8073	5766	4036	2883	2018	1468	1009	734	505	367	252	183
200		10333	7381	5167	3690	2583	1845	1292	939	646	470	323	235	161	117
180		8370	5979	4185	2989	2093	1495	1046	761	523	380	262	190	131	95
160		6613	4724	3307	2362	1653	1181	827	601	413	301	207	150	103	75
140		5063	3617	2532	1808	1266	904	633	460	316	230	158	115	79	58
120		3720	2657	1860	1329	930	664	465	338	233	169	116	85	58	42
100		2583	1845	1292	923	646	461	323	235	161	117	81	59	40	29
90		2093	1495	1046	747	523	374	262	190	131	95	65	48	33	24
80		1653	1181	827	590	413	295	207	150	103	75	52	38	26	19
70		1266	904	633	452	316	226	158	115	79	58	40	29	20	14
60		930	664	465	332	233	166	116	85	58	42	29	21	15	11
50		646	461	323	231	161	115	81	59	40	29	20	15	10	7
45		523	374	262	187	131	93	65	48	33	24	16	12	8	6
40		413	295	207	148	103	74	52	38	26	19	13	9	6	5
35		316	226	158	113	79	57	40	29	20	14	10	7	5	4
30		233	166	116	83	58	42	29	21	15	11	7	5	4	3
25		161	115	81	58	40	29	20	15	10	7	5	4	3	2
20		103	74	52	37	26	18	13	9	6	5	3	2	2	1
18		84	60	42	30	21	15	10	8	5	4	3	2	1	1
16		66	47	33	24	17	12	8	6	4	3	2	2	1	1
14		51	36	25	18	13	9	6	5	3	2	2	1	1	1
12		37	27	19	13	9	7	5	3	2	2	1	1	1	
10		26	18	13	9	6	5	3	2	2	1	1	1		

13.3.3.2 Hyperfocal distances (meters)

Circle of Confusion (mm)	Aperture													
0.05					1	1.4	2	2.8	4	5.6	8	11	16	22
0.035				1	1.4	2	2.8	4	5.6	8	11	16	22	
0.025			1	1.4	2	2.8	4	5.6	8	11	16	22		
0.017		1	1.4	2	2.8	4	5.6	8	11	16	22			
0.0125	1	1.4	2	2.8	4	5.6	8	11	16	22				
Lens focal length (mm)	Hyperfocal distance (Meters)													
250	5000	3571	2500	1786	1250	893	625	455	313	227	156	114	78	57
200	3200	2286	1600	1143	800	571	400	291	200	145	100	73	50	36
180	2592	1851	1296	926	648	463	324	236	162	118	81	59	41	29
160	2048	1463	1024	731	512	366	256	186	128	93	64	47	32	23
140	1568	1120	784	560	392	280	196	143	98	71	49	36	25	18
120	1152	823	576	411	288	206	144	105	72	52	36	26	18	13
100	800	571	400	286	200	143	100	73	50	36	25	18	13	9.1
90	648	463	324	231	162	116	81	59	41	29	20	15	10	7.4
80	512	366	256	183	128	91	64	47	32	23	16	12	8	5.8
70	392	280	196	140	98	70	49	36	25	18	12	8.9	6.1	4.5
60	288	206	144	103	72	51	36	26	18	13	9	6.5	4.5	3.3
50	200	143	100	71	50	36	25	18	13	9.1	6.3	4.5	3.1	2.3
45	162	116	81	58	41	29	20	15	10	7.4	5.1	3.7	2.5	1.8
40	128	91	64	46	32	23	16	12	8	5.8	4	2.9	2	1.5
35	98	70	49	35	25	18	12	8.9	6.1	4.5	3.1	2.2	1.5	1.1
30	72	51	36	26	18	13	9	6.5	4.5	3.3	2.3	1.6	1.1	0.8
25	50	36	25	18	13	8.9	6.3	4.5	3.1	2.3	1.6	1.1	0.8	0.6
20	32	23	16	11	8	5.7	4	2.9	2	1.5	1	0.7	0.5	0.4
18	26	19	13	9.3	6.5	4.6	3.2	2.4	1.6	1.2	0.8	0.6	0.4	0.3
16	20	15	10	7.3	5.1	3.7	2.6	1.9	1.3	0.9	0.6	0.5	0.3	0.2
14	16	11	7.8	5.6	3.9	2.8	2	1.4	1	0.7	0.5	0.4	0.2	0.2
12	12	8.2	5.8	4.1	2.9	2.1	1.4	1	0.7	0.5	0.4	0.3	0.2	0.1
10	8	5.7	4	2.9	2	1.4	1	0.7	0.5	0.4	0.3	0.2	0.1	0.1

13.4 LENS PRINCIPAL POINTS

All lenses have four principal points, the entrance pupil, the front and rear nodal points and the exit pupil.

Put very simply, if all the rays of light converging on a lens from all angles were to be traced like a massive bundle of strings, the point at which they would all appear to meet is the 'front entrance pupil'. The 'front nodal point' is the point where the angular spread of light rays entering the lens from the object is the same as that exiting the lens towards the image.

Similar conditions occur at the rear of a lens where the rays emerge. These are the rear nodal point and the exit pupil.

13.4.1 Front nodal point position

A knowledge of the position of the front nodal point is important to a cameraman because it is from this point that depth of field calculations are made and about which a camera can be panned and tilted without the image being displaced. This is particularly useful when shooting miniatures, ultra close-ups, front projection and glass matte shots.

With multi-element lenses the position of the front nodal point bears no apparent rational relationship to the focal length or to any other lens of similar type, focal length or manufacturer. The front nodal point positions listed below are supplied by the lens manufacturers. They are measured from the front vertex of the lens and remain constant, except at close focus distances, as the lens is focused. Alternatively the front entrance pupil may be found by mounting the lens on a camera on a pan and tilt head which has a balancing slide. See Sections 7.4.6 and 7.4.7 for details.

FRONT NODAL POINT POSITION LOOK-UP TABLES

All front nodal point positions are from the vertex of the front element rearwards towards the image plane:

ANGENIEUX 6 × 17mm ZOOM LENS

Focal length (mm)	17	20	25	40	75	100
Front nodal point position at Infinity (mm)	112.61	119.64	132.42	164.66	222.69	257.28
Front nodal point position at 2' 6" (0.75m)	107.70	114.79	128.07	163.59	233.31	277.53

Length of lens from vertex of front lens element to focal plane: 448.75mm

ANGENIEUX 6 × 20mm ZOOM LENS

Focal length (mm)	20	25	40	75	100	120
Front nodal point position at Infinity (mm)	95.99	111.22	154.40	228.81	272.27	302.25
Front nodal point position at 3'3" (1.0m)	98.86	112.68	153.90	231.10	279.18	313.51

Length of lens from vertex of front lens element to focal plane: 349.17 - 369.36 mm

ANGENIEUX 10 × 25mm T2 ZOOM LENS

Focal length (mm)	25	40	75	100	180	250
Front nodal point position at Infinity (mm)	87.09	140.08	230.72	272.61	330.99	320.06
Front nodal point position at 5' 7" (1.70m)	131.61	208.21	348.30	413.48	477.22	417.33

Length of lens from vertex of front lens element to focal plane: 308.37 - 328.10 mm

ANGENIEUX 10 × 25mm HP ZOOM LENS

Focal length (mm)	25	40	75	100	180	250
Front nodal point position at Infinity (mm)	95.01	147.43	238.34	280.82	342.84	336.27
Front nodal point position at 5' 7" (1.70m)	139.13	214.76	355.04	421.25	492.15	438.799

Length of lens from vertex of front lens element to focal plane: 318.27 - 337.91 mm

ANGENIEUX 10 × 25mm HR ZOOM LENS

Focal length (mm)	25	40	75	100	180	250
Front nodal point position at Infinity (mm)	67.32	122.01	217.94	264.33	342.49	354.73
Front nodal point position at 5' 7" (1.70m)	135.56	215.95	368.40	444.25	549.90	526.09

Length of lens from vertex of front lens element to focal plane: 349.61 mm

PANAVISION PRIMO PRIME (fixed focal length) LENSES

Focal length (mm)	Aperture	Front nodal point position rearwards from front vertex	Length of lens from front vertex to focal plane
10	T1.9	58.2 mm	199.8 mm
14.5	T1.9	53.0 mm	229.6 mm
17.5	T1.9	52.9 mm	216.7 mm
21	T1.9	64.0 mm	178.4 mm
27	T1.9	72.4 mm	203.2 mm
35	T1.9	67.5 mm	192.5 mm
40	T1.9	74.3 mm	191.0 mm
50	T1.9	93.2 mm	227.5 mm
75	T1.9	67.6 mm	114.6 mm
100	T1.9	86.2 mm	144.7 mm
150	T1.9	141.1 mm	200.2 mm

PANAVISION PRIMO 17.5 - 75mm T2.3 ZOOM LENS

Focal length	17.5	26	34	40	44	52	75
Front nodal point position at Infinity (mm)	77.4	95.3	109.9	118.9	124.4	133.0	150.0
Front nodal point position at 2ft 6in (0.769m)	78.2	98.0	114.4	124.7	130.8	140.4	157.7

Length of lens from vertex of front lens element to focal plane: 351.9 mm

PANAVISION PRIMO 3:1 (135 - 420mm) T2.8 ZOOM LENS

Focal length (mm)	135	200	270	340	420
Front nodal point position at Infinity (mm)	713.1	885.3	1008.0	1107.5	1198.1
Front nodal point position at 8ft 0in (2.40)	696.7	875.3	1009.3	1122.10	1222.5

Length of lens from vertex of front lens element to focal plane: 565.0 mm

PANAVISION PRIMO 11:1 (24 - 275mm) T2.8 ZOOM LENS

Focal length (mm)	24	50	100	150	275
Front nodal point position at Infinity (mm)	131.1	205.2	305.0	323.6	174.2
Front nodal point position at 4ft 0in (1.20)	123.9	199.5	311.6	314.1	159.1

Length of lens from vertex of front lens element to focal plane: 418.5 mm

RTH SPEED PANCHRO SERIES II & III (fixed focal length) LENSES

Focal length (mm)	Aperture	Front nodal point position rearwards from front vertex	Length of lens from front vertex to focal plane
18	T2.2	35mm	80.88
25	T2.2	33mm	73.28
32	T2.3	17mm	47.1
40	T2.3	22mm	57.59
50	T2.3	27mm	71.76
75	T2.3	17mm	93.90
100	T2.8	52mm	141.20
152	T3.2	37mm	179.30

RTH 14 - 70mm WIDE ANGLE COOKE VAROTAL ZOOM LENS

Focal length (mm)	14	20	29.5	45	70
Front nodal point position at Infinity (mm)	100.3	110.7	126.0	148.2	178.4

RTH 18 - 100mm COOKE VAROTAL ZOOM LENS

Focal length (mm)	18	27.5	40.8	62.3	100
Front nodal point position at Infinity (mm)	108.1	127.3	153.0	189.7	213.3
Front nodal point position at min object distance. (mm)	87.0	99.8	119.2	153.6	232.2

Length of lens from vertex of front lens element to focal plane: 369.3 mm

RTH 25 - 250mm CINETAL ZOOM LENS

Focal length (mm)	26	42.2	82.2	146.2	260
Front nodal point position at Infinity (mm)	102.4	151.4	238.4	350.6	477.8
Front nodal point position at min. object distance (mm)	107.0	206.6	367.5	638.2	1084.4

Length of lens from vertex of front lens element to focal plane: 379.7 mm

RTH 25 - 250mm CINE VAROTAL ZOOM LENS

Focal length (mm)	25	46.3	82.3	146.4	250
Front nodal point position at Infinity (mm)	102.4	181.6	286.8	406.6	469.0

RTH 9 - 50mm COOKE VAROKINETAL ZOOM LENS

Focal length (mm)	9	12.6	18.3	28.2	50
Front nodal point position at Infinity (mm)	61.2	70.7	86.2	1137	163.5
Front nodal point position at min. object distance (mm)	49.7	56.5	67.5	86.8	125.3

Length of lens from vertex of front lens element to focal plane: 222.4 mm

ZEISS FIXED FOCAL LENGTH LENSES

Focal length (mm)	Aperture (T)	Front nodal point position rearwards from front vertex	Length of lens from front vertex to focal plane
9.5 (16mm only)	1.3	40.8	109.6
12 (16mm only)	1.3	46.6	115.3
16 (16mm only)	1.3	43.5	101.3
18	1.3	46.6	139.3
25	1.3	46.3	104.1
35	1.3	53.3	105.3
50	1.3	54.6	84.9
65	1.3	69.8	108.0
85	1.3	53.3	114.0
8 (16mm only)	2.1	30.9	83.9
10	2.1	54.5	193.9
14	2.0	51.2	162.9
16	2.1	34.1	93.2
20	2.1	32.4	88.3
24	2.1	43.7	81.7
28	2.1	42.8	117.7
32	2.1	18.0	44.2
40	2.1	21.7	53.7
50	2.1	34.5	77.9
60	3.0 Macro	25.2	77.9
85	2.1	36.6	97.1
100	2.1	48.8	125.8
135	2.1	24.6	142.1
180	2.1	-9.6	172.3
300	2.1	-138	286.3

ZEISS 10 - 100mm T2.1 16mm ZOOM LENS

Focal length (mm)					
Front nodal point position at Infinity (mm)					

ZEISS 11 - 110mm T2.2 16mm ZOOM LENS

Focal length (mm)	11				110
Front nodal point position at Infinity (mm)	52.9				369.4

13.5 LENS TESTING

All lens designs are a compromise between definition and contrast, between good performance in the central area and acceptable performance in the corners of the image area and between good performance at optimum aperture and having a useful maximum aperture. Many lenses would be good if they had only to photograph mid-gray objects in the center of the image area when well stopped down from maximum aperture.

13.5.1 Lens defects

It is not just a simple matter to design and manufacture a lens where a series of parallel straight lines on a test chart photograph parallel at the extreme top and bottom of the picture area (barrel or pincushion distortion), where vertical and horizontal lines are always equally well defined (astigmatism) and there is no color fringing or lateral color in the extreme corners of the photographed area.

* Some lenses give optimum results reproducing a curved surface rather than a flat one (curvature of field).

* Some lenses shift focus when they are stopped down or opened up. This often occurs in wide aperture lenses between full aperture and two stops stopped down (spherical aberration)

* Some zoom lenses change focal length as they are focused (breathing)

* Some zoom lenses have focal lengths where the definition falls off sharply, only to improve again as they pass that point.

* The index line for optimum focus on some zoom lenses changes both with aperture and focal length (spherical aberration leading to axial tracking error).

* Some zoom lenses do not track in a straight line down the optical axis.

* Ultra wide aperture lenses usually have more inherent aberrations at full aperture than lenses with smaller apertures.

* Lens performance usually improves markedly as a lens is stopped down from full aperture but after two or three stops may deteriorate again and be worse at the smallest aperture than full open. (This is often due to a physical phenomenon known as diffraction which causes light to spread and flare when it is passed through a narrow space, which is why some lenses only stop down to f/11 or 16.)

* Lenses which have spread-out lens scales may appear to have more focus shift at full aperture than those which have compressed scaling but it may well be that the compressed scaling only hides the problem.

* Different lenses, even from the same series from the same manufacturer, may differ in the reproduction of color or contrast, and so on.

* Not even the position of an infinity mark on long telephoto lenses can be relied upon to be constant as some distant objects many miles away may appear to be closer or further away when there is dust or moisture in the air than when the air is clean (this is not a lens fault but a fact of life).

* Temperature differences which cause lens and camera mountings to shrink or expand can also affect lens scaling, particularly at infinity.

Cinematographers must accept that all these faults do exist to a greater or lesser degree in all lenses and carry out tests to determine how they may get the best possible performance out of the lenses at their disposal.

13.5.2 Flange focal depth

Before shooting a lens test it is necessary to check that the flange focal distances of all cameras to be used are within the manufacturer's tolerances. See Section 5.3 for more information.

Flange focal depth accuracy is most important with short focal length and ultra wide angle lenses. It is crucially important with zoom lenses to ensure that the infinity of a zoom lens remains constant within acceptable limits throughout the zoom range.

13.5.3 Auto-collimators

An auto-collimator can be used to check the infinity calibration of lenses, relative to the surface of the film, *in situ* on a camera. Consideration must, however, be given to the fact that the manufacturer may have set the point of focus into the emulsion and not on the surface of the film.

An auto-collimator should be used in conjunction with new film in the gate and the camera running to check that the lens/camera combination is good under working conditions.

A major flaw with auto-collimators is that the measuring light passes through the test lens twice – once to the image and again upon return – causing some lens aberrations to be cancelled out and some to accumulate. Typically this will cause a measurement error of about ±0.0015" (±0.038mm).

13.5.4 Checking the ground glass setting

When checking the lens scaling by eye focus for subsequent focusing by tape measure it is first necessary to check that the ground glass is set correctly relative to the film plane and then to check the scaling accuracy at all the marked distances and at various apertures (many lenses are scaled to be most accurate at f/4 and may be considerably less accurate at full aperture). However, there is no point in checking the ground glass settings with a lens aperture set wider than the aperture of the viewfinder system, which in most cases is also about f/4. (Eye focusing a lens set at, say, f/1.2 may prove to be inaccurate if the lens has a considerable focus shift at full aperture and the viewfinder system has an aperture of only f/4.)

An auto-collimator may also be used to check the accuracy of the setting of the ground glass. This can be done by setting the camera's mirror shutter to the view position and checking that the auto-collimator image is as good when looking at the ground glass as when looking at the surface of the film.

If the camera manufacturer has specified that the point of focus should be set into the emulsion of the film it follows that the flange focal distance to the ground glass will be different from the distance to the surface of the film. This too must be taken into consideration when using an auto-collimator to check the ground glass setting.

13.5.5 Mechanical checking

Lenses must also be checked mechanically, that front or rear elements are not badly scratched (small specks of dirt inside the lens are not important), that there are no bright patches of metal inside the lens or on the edges of the blades of the iris that might flare, that the iris functions correctly and that there is no backlash in the iris or the focus and that the lens does not rattle when shaken, indicating a loose element.

Special care should be taken when checking a set of lenses that they all have the same focusing (and zoom) feel and that none are looser or tighter than others. The initial 'stiction' of focusing a zoom movement is also important and should be barely noticeable.

If lenses are to be used in abnormally cold conditions they should be tested beforehand at the temperature range that is expected, leaving them overnight in an environmental test chamber, or even a deep freeze, before checking the focus and zoom movements.

Special care should also be taken when checking lenses which were originally designed and manufactured for use on still cameras that they have the same mechanical quality, as well as optical quality, as lenses especially designed for motion picture usage.

The rear surface of the lens mount should also be checked for cleanliness.

13.5.6 Photographic lens testing

Although lens testing by MTF is the most efficient means of measuring lens performance (see Section 13.5.8) and the auto-collimator (used with due care and consideration) is a useful tool for checking variations in lens and ground glass settings, it is only photographic testing which can satisfactorily evaluate the entire cinematographic chain.

Having checked that the mechanical distances of all the cameras and all lenses to be used on a particular shot are within tolerances, and that the lens is mechanically sound, photographic assessments should be made of all lenses.

To shoot photographic tests it is usual to set up a test chart which must be evenly illuminated. Care must be taken when setting the lighting to place the lamps no less than the width of the test chart on either side of the camera so that the light cannot reflect back into the lens causing flare and reducing optical performance.

Ideal targets are lens definition charts which incorporate a series of pairs of lines in both horizontal and vertical directions. The normal practice is to set a number of these charts in the center, edges and corners of the picture area within the format to be used.

A test chart should be sufficiently large to fill the entire image format using the widest angle lens to be tested. If the widest angle lens has a restricted close focusing ability (some zoom lenses cannot focus closer than 4' 6", 1.5m.) then this, too, should be taken into consideration when setting up the test chart. 25 times the image width is usually considered to be a reasonable size for a test chart but if some lenses have restricted focusing ability it may be necessary to go to 40x, or larger.

Having set the minimum size of the test chart to suit the widest angle lens at its closest focusing distance the distance between the chart and the camera should then be increased for longer focal length lenses so that the image magnification remains constant. Meaningful comparisons can then be made between the performances of any number of fixed focal length lenses and of zoom lenses at various focal length settings.

Charts in the corners of the picture should be set with their lines parallel/perpendicular to the diagonal of the picture rather than to the edges of the frame so that the axial and tangential performances of the lens may be judged separately (astigmatism).

Test charts should contain some large areas of black adjoining equally large areas of white, particularly near the corners, so that any coma or chromatic aberrations show up.

Test charts may also include the following:

* A gray scale to check contrast, flare and the tonal range

* One or more 'Siemens stars' (a series of radial lines like the spokes of a wheel) the center of which will appear to be blurred upon reproduction and is an indication of the spatial frequency range of the cinematographic chain. Siemens stars are also particularly good for eye focusing, for visually checking the definition/contrast performance, and, when double exposed, for testing camera image steadiness

* Photographs of dark and/or fair skinned models (to match those who will appear in the movie) to check the film's ability to reproduce skin tones

* A series of large circles to check the geometry of anamorphic lenses at different focusing distances

* A large black patch, or other surface, on which test information can be clearly written and then erased when finished with

* A series of arrows pointing to the edges of the image area to check for cut-off and vignetting. (Infinity and full aperture are the critical parameters for vignetting.)

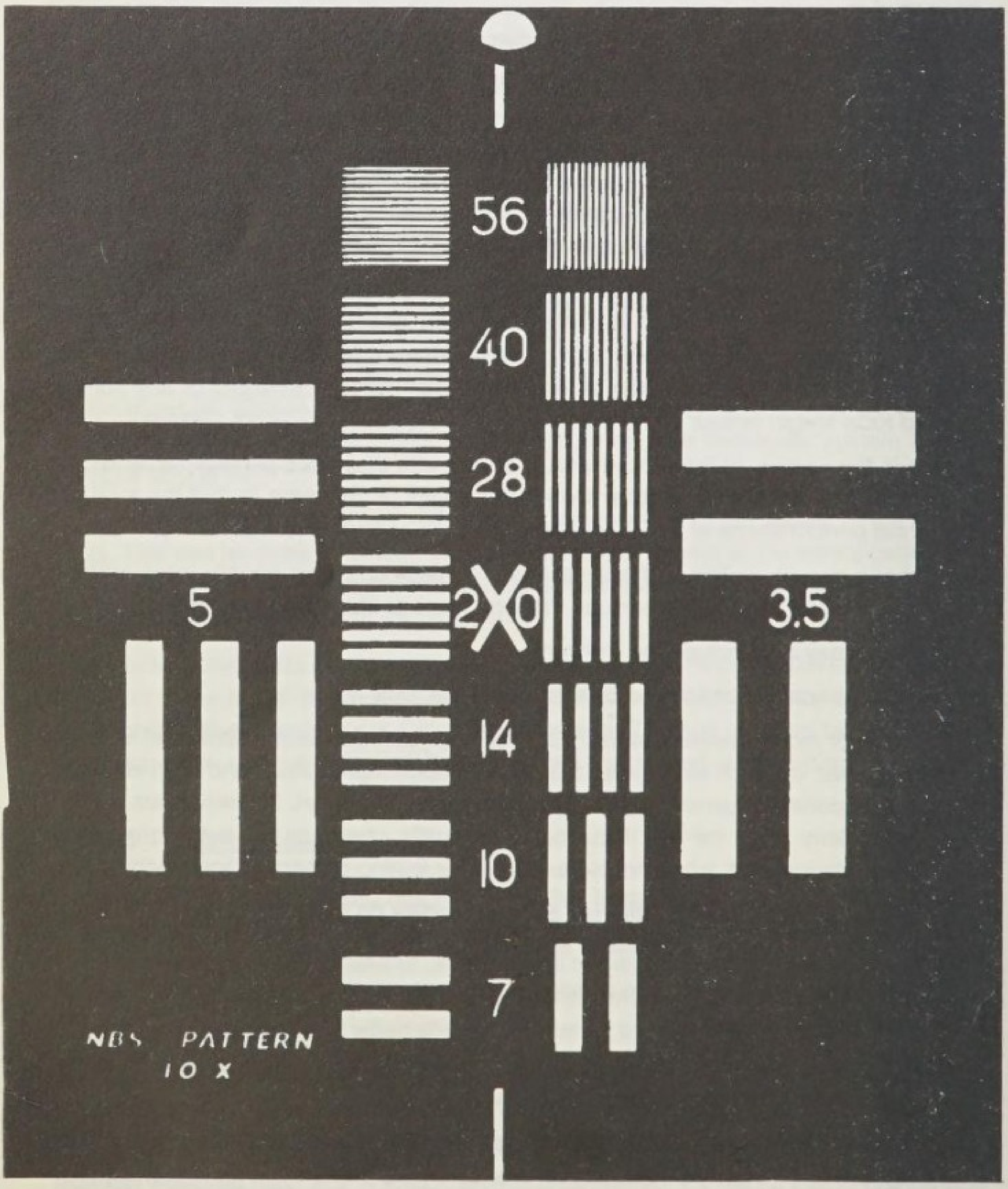
Focus charts may either be printed on non-reflective paper using a jet black ink or be transparencies illuminated from behind.

Care should be taken to ensure that no bright object even outside the picture area is shining into the lens and that the lens is adequately hooded and flagged.

If a routine lens test is being made for subsequent viewing by projection it is necessary to shoot a sufficient length of film to give ample opportunity to check all the necessary information. If, however, the lens test is to be checked by examination under a microscope then only a very brief shot is necessary.

When photographing test charts a good way to check for optimum focus settings and focus shift is to attach a small strip of graph paper over the focus index mark and then to shoot a series of tests not only at the position of the index mark but also at plus and minus, say, 1mm, 2mm and 3mm at various apertures. In this manner the best possible point of focus can be found for each lens and any focus shifts noted and allowed for when the particular lens is in use.

When testing anamorphic lenses it is neccessary to concentrate on the so called 'sweet spot', an oval shaped area 10% inside the full rectangular anamorphic format. The definition of even the best anamorphic lenses will fall off in the corners of a flat test chart.



FOCUS TEST TARGET (full size): The numbers indicate the number of black/white line interfaces per inch on the test target.

13.5.7 Assessing lens performance

Before viewing lens tests by projection it is as well to have the projectionist run an SMPTE test film through the projector beforehand to see what the limitations of the projection system are. A test film will show if the projector focus is good all over, if a good contrasty image is possible, if it is steady and, in the case of anamorphic tests, if the projector anamorphic lenses can show circles as circles.

If examining tests under a microscope, a 25× magnification is recommended.

When viewing a lens test the most important aspect to note is the overall definition *combined* with contrast. Both should be displayed in full measure. A lens resolving a lot of fine detail but with no deep blacks and bright whites is of little use. A lens which produces no deep blacks may be suffering from a fault called 'veiling glare'.

Note should then be taken of the following:

* The amount of fall-off in the corners of the image area compared with the center.
* The definition of horizontal lines compared with vertical lines.
* The straightness of lines across the top and bottom of the frame.
* The amount of flare and color fringing at the intersection of black and white areas.
* The overall color bias and exposure density compared to other lenses to be used.

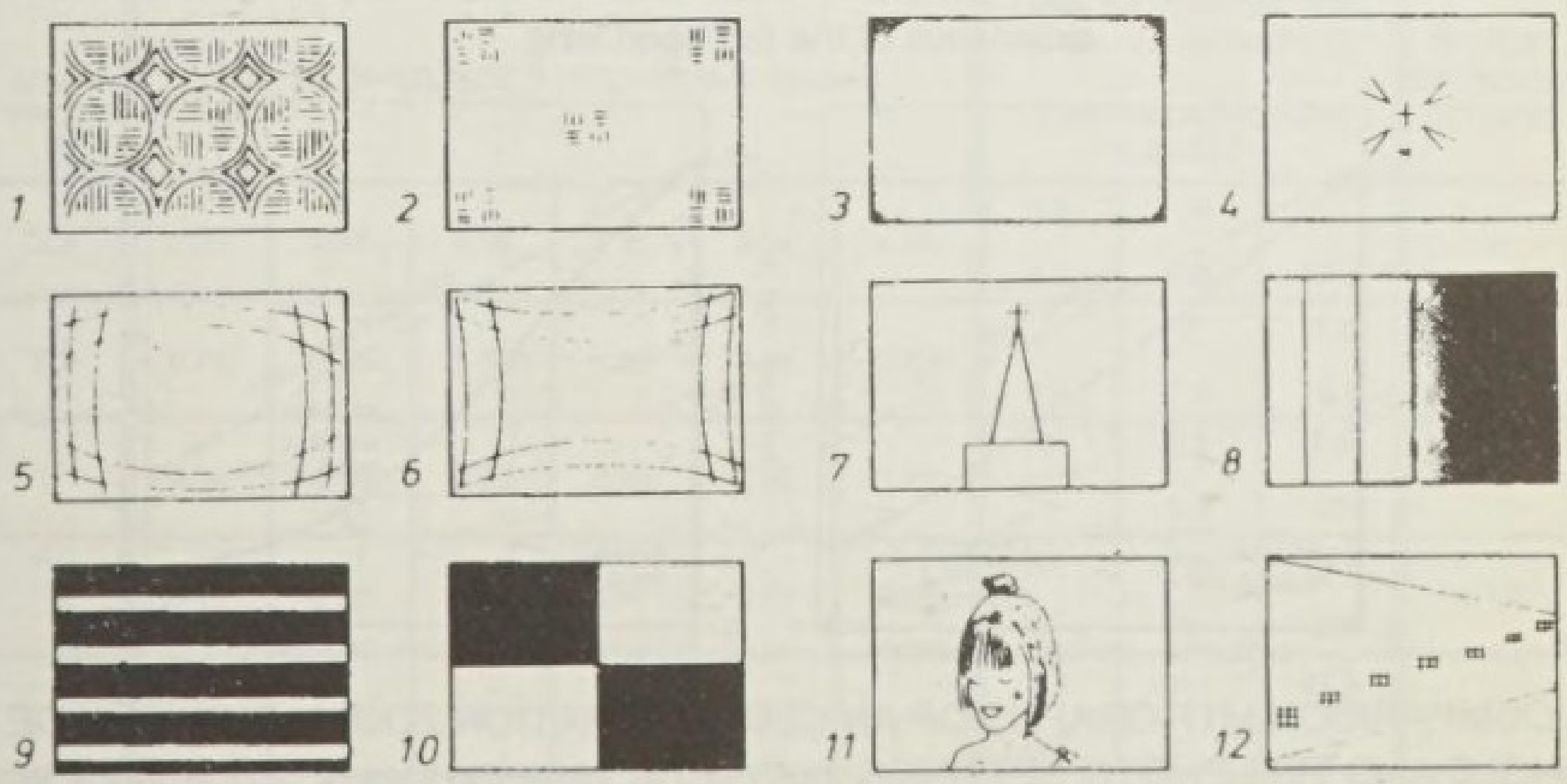
When testing zoom lenses it is also necessary to check the following:

* The comparison of definition and contrast at different focal lengths.
* Any change in image size while changing focus or aperture (breathing).
* Any additional vignetting at the widest angle/closest focusing distance.
* That the lens tracks in an acceptably straight line as it is zoomed in and out.

When checking anamorphic lenses it is also necessary to check the following:

* There is no 'mumps effect', i.e. circles remain circles at close focus distances
* There is no breathing effect, i.e. image size does not change with focus
* Good image quality is maintained over the whole focus range

Remember, no lens is perfect, that unless you are shooting on an animation stand you are unlikely to be filming objects or scenes that are as flat, or as uninteresting, as a focus chart and that no two lenses are the same.



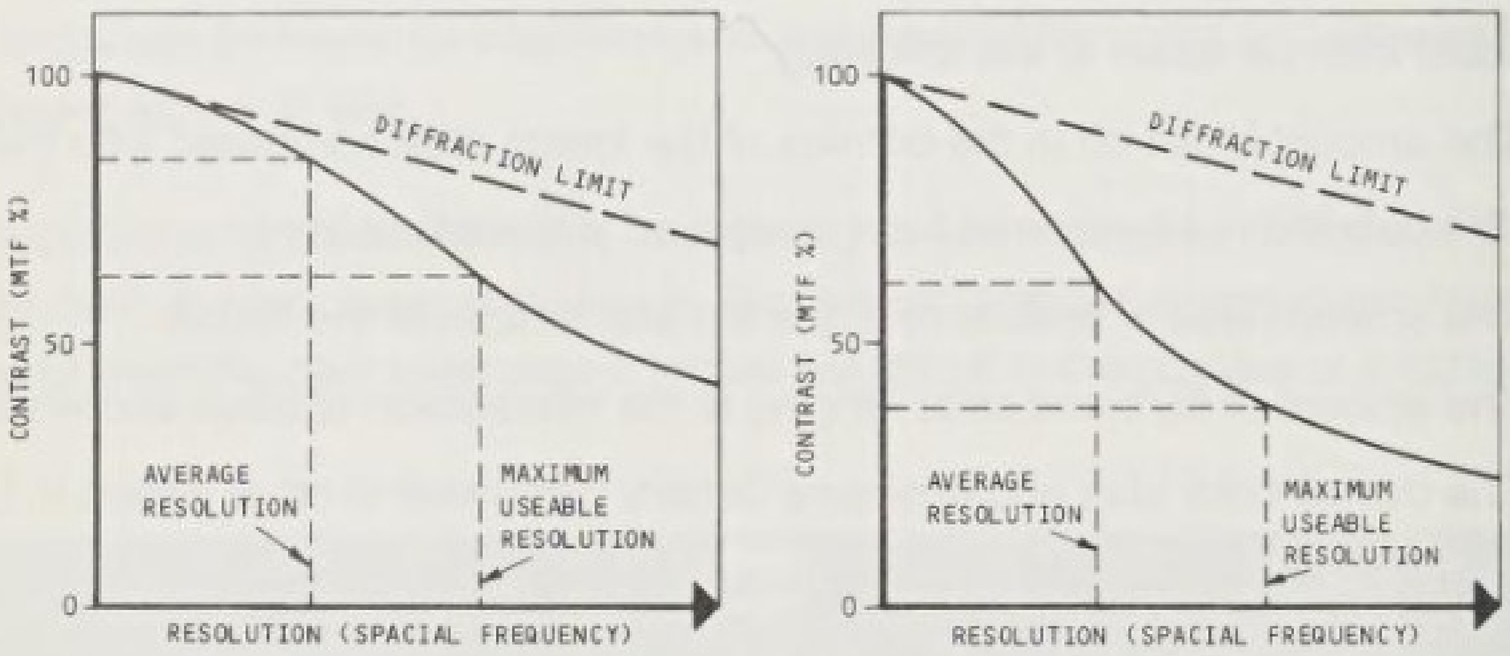
QUALITIES BY WHICH LENSES ARE ASSESSED: 1. Good resolution; 2. Good off-axis and central performance; 3. No vignetting; 4. Minimum axial drift and no loss of definition while zooming; 5. Minimum barrel or, 6. pincushion distortion; 7. Good infinity focus, no change in image size during change of focus; 8. Aperture (exposure) and color consistent between different lenses; 9. Minimal color fringing; 10. Good contrast with dense blacks and clear whites with no veiling glare; 11. Good flesh tone color; 12. Acceptable figures for extremes of field depth.

13.5.8 Checking lenses by MTF

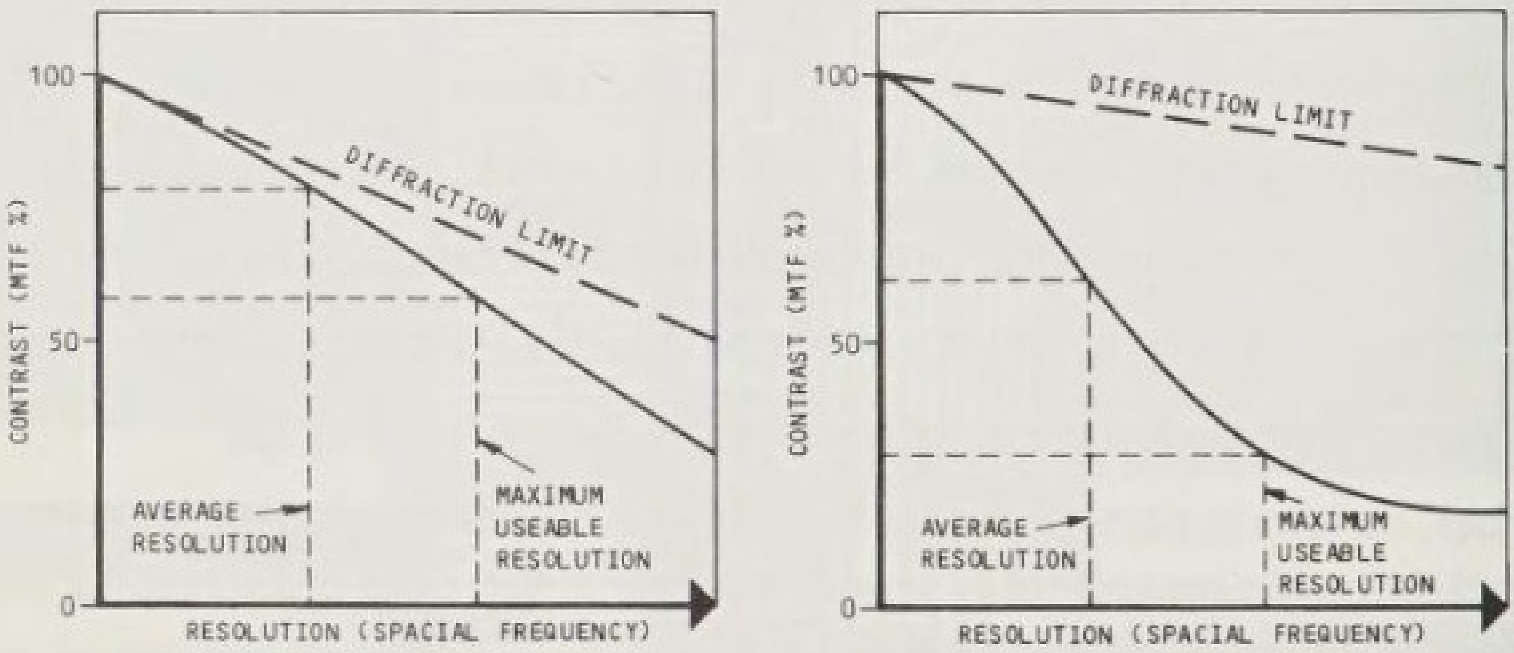
Lens manufacturers and the larger camera equipment rental companies check the performance of lenses by a laboratory method known as MTF (Modulation Transfer Function).

On a MTF bench it is possible to quantify the definition/contrast capability of a lens related to the definition/contrast capability of the motion picture image chain, i.e. the negative film stock, the printer limitations, the print stock and the projection system limitations.

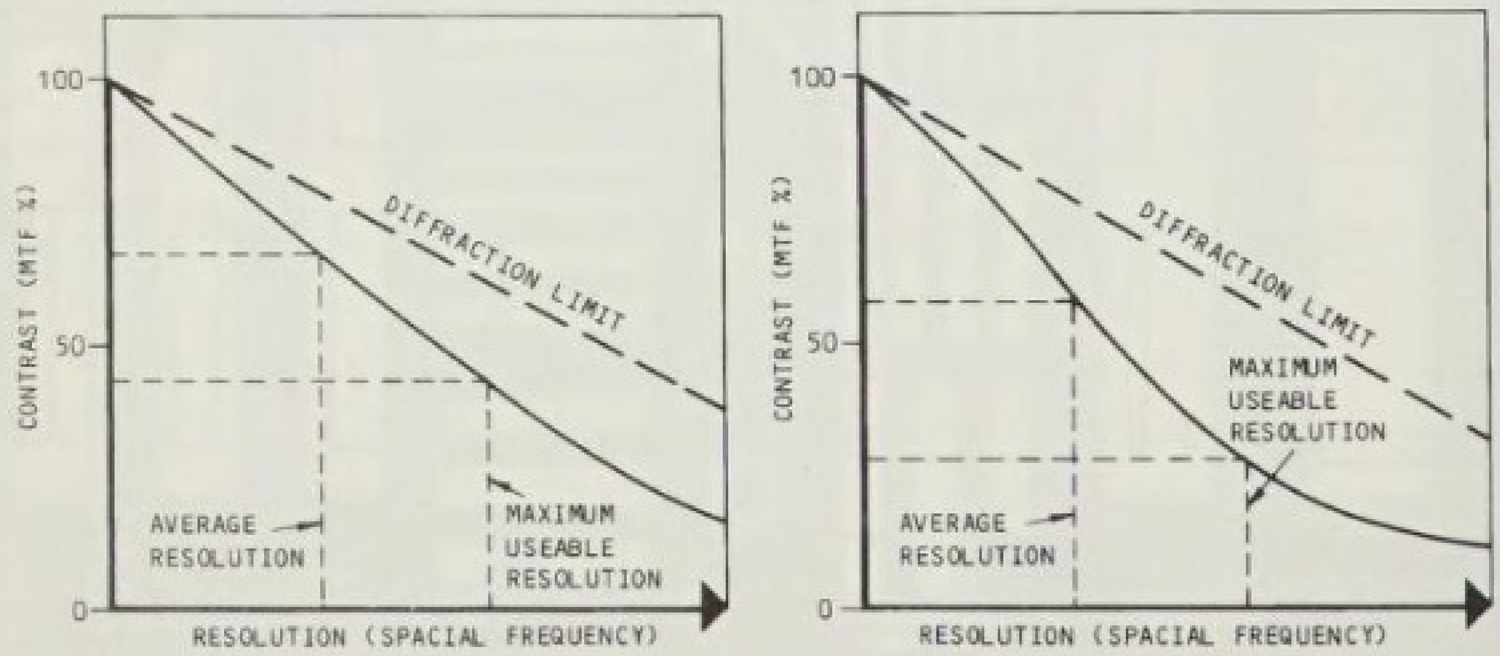
Performance can be checked both at the center of the image (on-axis) and at any point across the full width of the image area (off-axis), horizontally and vertically (astigmatism), at any back focal distance (focus setting) and at any aperture (focus shift). Other lens characteristics which can be detected and quantified on an MTF bench include veiling glare (an overall fogging effect which affects the overall lens performance).



1. MTF GRAPHS OF A TYPICAL LENS AT T2.8 (left) AND AT T1.3 (right). Note that there is a significant loss of both contrast and resolution at full aperture.



2. COMPARISON MTF GRAPHS OF A HIGH PERFORMANCE LENS (Panavision PRIMO) AND A STANDARD LENS (both at T2). Note the superior performance characteristics of the left hand lens.



3. COMPARISON MTF GRAPHS OF AN OLD GENERATION ZOOM LENS AT WIDE ANGLE AND TELEPHOTO SETTINGS (both at T4). Note the loss of performance at the long end (right hand graph) of the zoom range.

13.5.9 Checking color transmission

In the lens laboratory the color transmission characteristics of lenses can be checked with immense accuracy with a spectrophotometer.

The set of lenses to be used on a particular shoot can be compared by projecting a light through each lens and using a color temperature meter.

13.5.10 Checking filters

If glass filters (particularly those made of gelatine sandwiched between two pieces of thin glass) are to be used they should be checked with the same thoroughness as the lenses. (See Section 12.1.)

Filters also need to be checked for consistency of color and effect (the lens focal length and the closeness of the filter to the front element of the lens will affect performance).

13.6 MACRO CINEMATOGRAPHY

Whenever an object is less than 10 focal lengths away from the camera the exposure must be increased beyond that calibrated on the lens to compensate for the extra amount by which the light is dispersed. See Section 15.6.7 for formulae.

The image:object size ratio (the amount of magnification) is referred to as the 'magnification ratio' of a picture. The first number always refers to the size of the image on the film and the second to the size of the object to be photographed (as seen from the motor side of the camera). The magnification ratio takes no account of film size. A 1:1 magnification ratio implies that the image is the same size as the object and for this ratio the amount of extension required is twice the focal length.

The magnification factor is the image size divided by the object size.

Extension rings or tubes may be used for additional magnification (not suitable for use with anamorphic, wide angle or zoom lenses).

Lenses designed for normal usage may give better results if used in reverse for macro work.

As with all photography, the amount it is possible to stop down a lens is limited by diffraction. See Section 13.7.

MACRO LENS EXTENSION TABLE

	FORMAT									
	STD'16	SUP'16	ACAD'	FULL F'	VISTA V'	65mm				
	FRAME WIDTH (Projector)						LENS FOCAL LENGTH(mm)			
Inches	0.378	0.463	0.825	0.945	1.418	1.913	50	100	200	
mm	9.6	11.76	20.96	24.00	36.01	48.59				
MAG'-FACTOR	WIDTH OF OBJECT TO FILL FRAME (Inches)						LENS EXTENSION FORWARD OF INFINITY (") LENS TO OBJECT DISTANCE (")			EXPOS' INCREASE (STOPS)
0.4	0.95	1.16	2.06	2.36	3.54	4.78	0.8 4.9	1.6 9.8	3.1 19.7	1
0.5	0.76	0.93	1.65	1.89	2.84	3.83	1 3.9	2 7.9	3.9 15.7	11/4
1	0.38	0.46	0.83	0.95	1.42	1.91	2 2	3.9 3.9	7.9 7.9	2
2	0.19	0.23	0.41	0.47	0.71	0.96	3.9 1	7.9 2	15.7 3.9	3 1/8
4	0.09	0.12	0.21	0.24	0.35	0.48	7.9 0.5	15.7 1	31.5 2	41/2
8	0.05	0.06	0.1	0.12	0.18	0.24	15.7 0.2	31.5 0.5	63 1	61/4

MAGNIFICATION/OBJECT SIZE/DISTANCES/EXPOSURE CORRECTION

MACRO MAGNIFICATION FACTOR LOOK-UP TABLE

	FORMAT							
	STANDARD 16	SUPER 16	ACADEMY	FULL FRAME	VISTA-VISION	65mm	1/2" VIDEO	2/3" VIDEO
	IMAGE WIDTH							
Inches	0.378	0.463	0.825	0.945	1.418	1.913	0.5	0.667
mm	9.6	11.76	20.96	24.00	36.01	48.59	12.7	16.93
	ASPECT RATIO							
	1.33:1	1.69:1	1.37:1	1.33:1	1.5:1	2.2:1	1.33:1	1.33:1
OBJECT WIDTH (inches)	MAGNIFICATION FACTOR							
5	0.08	0.09	0.17	0.19	0.28	0.38	0.1	0.13
4	0.09	0.12	0.21	0.24	0.35	0.48	0.13	0.17
3	0.13	0.15	0.28	0.32	0.47	0.64	0.17	0.22
2	0.19	0.23	0.41	0.47	0.71	0.96	0.25	0.33
1.5	0.25	0.31	0.55	0.63	0.95	1.28	0.33	0.44
1	0.38	0.46	0.83	0.95	1.42	1.91	0.5	0.67
0.8	0.47	0.58	1.03	1.18	1.77	2.39	0.63	0.83
0.6	0.63	0.77	1.38	1.58	2.36	3.19	0.83	1.11
0.5	0.76	0.93	1.65	1.89	2.84	3.83	1	1.33
0.4	0.95	1.16	2.06	2.36	3.54	4.78	1.25	1.67
0.3	1.26	1.54	2.75	3.15	4.73	6.38	1.67	2.22
0.2	1.89	2.32	4.12	4.72	7.09	9.57	2.5	3.34
0.1	3.78	4.63	8.25	9.45	14.18	19.13	5	6.67
OBJECT WIDTH (mm)	MAGNIFICATION FACTOR							
150	0.06	0.08	0.14	0.16	0.24	0.32	0.08	0.11
140	0.07	0.09	0.15	0.17	0.26	0.35	0.09	0.12
130	0.07	0.09	0.16	0.18	0.28	0.37	0.1	0.13
120	0.08	0.1	0.17	0.2	0.3	0.4	0.11	0.14
110	0.09	0.11	0.19	0.22	0.33	0.44	0.12	0.15
100	0.1	0.12	0.21	0.24	0.36	0.49	0.13	0.17
90	0.11	0.13	0.23	0.27	0.4	0.54	0.14	0.19
80	0.12	0.15	0.26	0.3	0.45	0.61	0.16	0.21
70	0.14	0.17	0.3	0.34	0.51	0.69	0.18	0.24
60	0.16	0.2	0.35	0.4	0.6	0.81	0.21	0.28
50	0.19	0.24	0.42	0.48	0.72	0.97	0.25	0.34
40	0.24	0.29	0.52	0.6	0.9	1.21	0.32	0.42
30	0.32	0.39	0.7	0.8	1.2	1.62	0.42	0.56
20	0.48	0.59	1.05	1.2	1.8	2.43	0.64	0.85
10	0.96	1.18	2.1	2.4	3.6	4.86	1.27	1.69
9	1.07	1.31	2.33	2.67	4.0	5.4	1.41	1.88
8	1.2	1.47	2.62	3.0	4.5	6.07	1.59	2.12
7	1.37	1.68	2.99	3.43	5.14	6.94	1.81	2.42
6	1.6	1.96	3.49	4.0	6.0	8.1	2.12	2.82
5	1.92	2.35	4.19	4.8	7.2	9.72	2.54	3.39
4	2.4	2.94	5.24	6.0	9.0	12.15	3.18	4.23
3	3.2	3.92	6.99	8.0	12.0	16.2	4.23	5.64
2	4.8	5.88	10.48	12.0	18.01	24.3	6.35	8.47
1	9.6	11.76	20.96	24.0	36.01	48.59	12.7	16.93

Given the format or image width, and the object width, the table shows the MAGNIFICATION FACTOR.

MACRO CORRECTED APERTURE TABLE

	MAGNIFICATION RATIO								
	1:8	1:4	1:2	1:1	2:1	4:1	8:1	16:1	32:1
	MAGNIFICATION FACTOR								
	0.125	0.25	0.5	1	2	4	8	16	32
METER STOP	CORRECTED APERTURE								
32	28.3	25.6	21.3	16	10.7	6.4	3.6	1.9	1
22	19.5	17.6	14.7	11	7.3	4.4	2.4	1.3	
16	14.2	12.8	10.7	8	5.3	3.2	1.8		
11	9.7	8.8	7.3	5.5	3.7	2.2	1.2		
8	7.1	6.4	5.3	4	2.7	1.6			
5.6	5	4.5	3.7	2.8	1.9	1.1			
4	3.5	3.2	2.7	2	1.3				
2.8	2.5	2.2	1.9	1.4					
2	1.8	1.6	1.3						
1.4	1.2								

Given the magnification and the exposure meter reading the table shows the CORRECTED EXPOSURE for macro cinematography.

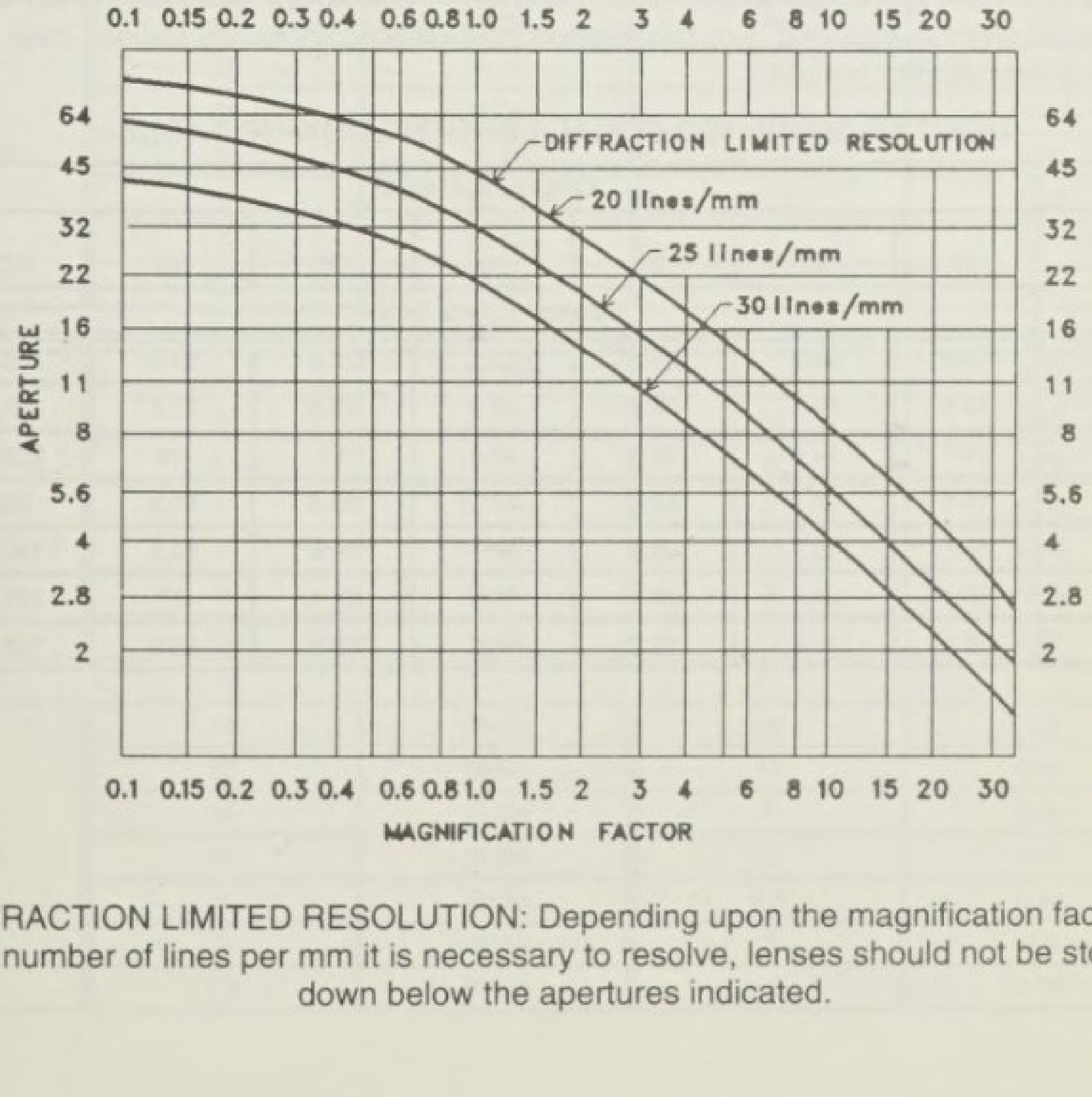
13.7 DIFFRACTION LIMITATION

There is a physical limit to the maximum contrast/resolution that can be achieved by any lens at a given aperture. This is caused by the rays of light spreading out as they pass through a small aperture and is known as the 'Diffraction Limit'. It limits the minimum aperture that can usefully be used to achieve greater depth of field.

Diffraction is also influenced by the wavelength of the light, being greater at high (reddish) nanometer values. Thus macro images filmed by light lacking in red and infrared (daylight, metal halide or strobe light, etc., used with daylight type filmstock) will have less loss of definition due to diffraction than images photographed by low color temperature tungsten light. (See Section 14.4.2).

If a lens is stopped down beyond the diffraction limit nothing will be in focus anywhere.

DIFFRACTION LIMITATION GRAPH

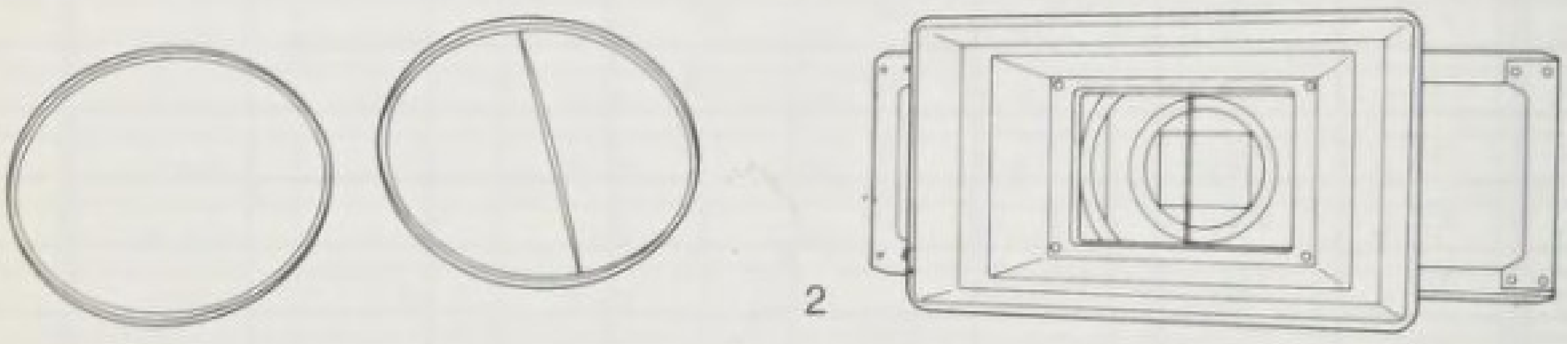


DIFFRACTION LIMITED RESOLUTION: Depending upon the magnification factor and the number of lines per mm it is necessary to resolve, lenses should not be stopped down below the apertures indicated.

13.8 OPTICAL ACCESSORIES

13.8.1 Diopter lenses

'Diopter' lenses are simple single element lens placed in front of a normal lens to enable the focus to be set closer than would otherwise be possible. In theory, a +1 diopter, which has a focal length of 1 meter, when placed in front of a lens focused on infinity will change the point of focus to 1 meter. In practice, with the large multi-element lenses (particularly zoom lenses) used for cinematography, this is not exactly so, the new point of focus falling some distance in front of 1 meter.



DIOPTER LENSES: 1. Full cover and split circular diopter lenses; 2. Sliding split diopter in front of an anamorphic lens.

'Split diopter lenses' are cut-down diopter lenses, with a straight edge, which can placed in front of only a part of the taking lens to enable two planes of focus to be photographed simultaneously. Diopter lenses are particularly useful when used with anamorphic lenses which cannot otherwise be focused very closely and with zoom lenses which cannot hold zoom focus if used with extension rings.

To use a split diopter:

1. Set the far distance focus according to the lens scale
2. Select a split diopter of approximately the correct diopter power
3. Set the split diopter in front of the taking lens with the convex surface towards the subject and with its straight edge aligned with a straight parallel line in the image area (a door or a pillar or the corner of a wall, etc.)
4. Place the foreground subject in position and move it backwards and forwards until it is in focus.

In this manner it is possible to focus on two distances at the same time.

Diopters cause the combined lenses to have a shorter focal length and thus the combined image to be slightly enlarged. For this reason split diopter shots are usually best done with low power diopter lenses.

DIOPTER COMBINED FOCAL LENGTH LOOK-UP TABLE

	Original focal length						
Diopter power	20	25	30	50	75	100	250
	Combined focal length						
0.25	19.9	24.8	29.8	49.4	73.6	97.6	235.3
0.5	19.8	24.7	29.6	48.8	72.3	95.2	222.2
0.75	19.7	24.5	29.3	48.2	71	93	210.5
1	19.6	24.4	29.1	47.6	69.8	90.9	200
1.25	19.5	24.2	28.9	47.1	68.6	88.9	190.5
1.5	19.4	24.1	28.7	46.5	67.4	87	181.8
2	19.2	23.8	28.3	45.5	65.2	83.3	166.7

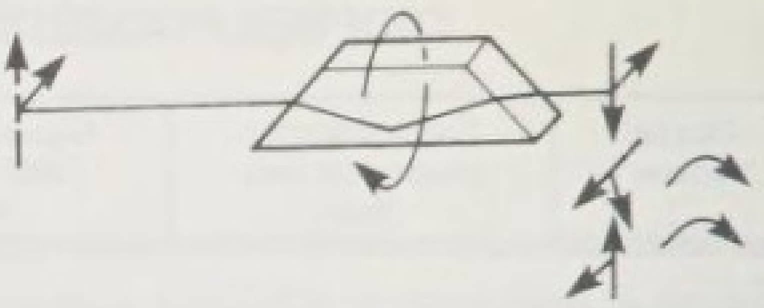
DIOPTER FOCUS DISTANCES LOOK-UP TABLE

Diopter power	Focus distance marked on lens (feet)	Focus distance with diopter (feet)	Focus distance marked on lens (meters)	Focus distance with diopter (meters)
+0.25	Inf	13ft 1in	Inf	4
	25	8ft 7in	10	2.86
	15	6ft 12in	5	2.22
	10	5ft 8in	3	1.71
	6	4ft 1in	2.5	1.54
	5	3ft 7in	2	1.33
	4.5	3ft 4in	1.5	1.09
0.5	Inf	6ft 7in	Inf	2
	25	5ft 2in	10	1.67
	15	4ft 7in	5	1.43
	10	3ft 12in	3	1.2
	6	3ft 2in	2.5	1.11
	5	2ft 10in	2	1
	4.5	2ft 8in	1.5	0.86
0.75	Inf	4ft 4in	Inf	1.33
	25	3ft 9in	10	1.18
	15	3ft 5in	5	1.05
	10	3ft 1in	3	0.92
	6	2ft 6in	2.5	0.87
	5	2ft 4in	2	0.8
	4.5	2ft 3in	1.5	0.71
1	Inf	3ft 3in	Inf	1
	25	2ft 11in	10	0.91
	15	2ft 8in	5	0.83
	10	2ft 6in	3	0.75
	6	2ft 1in	2.5	0.71
	5	1ft 12in	2	0.67
	4.5	1ft 11in	1.5	0.6
1.25	Inf	2ft 7in	Inf	0.8
	25	2ft 5in	10	0.74
	15	2ft 3in	5	0.69
	10	2ft 1in	3	0.63
	6	1ft 10in	2.5	0.61
	5	1ft 9in	2	0.57
	4.5	1ft 8in	1.5	0.52
1.5	Inf	2ft 2in	Inf	0.67
	25	2ft 0in	10	0.63
	15	1ft 11in	5	0.59
	10	1ft 10in	3	0.55
	6	1ft 7in	2.5	0.53
	5	1ft 6in	2	0.5
	4.5	1ft 6in	1.5	0.46
2	Inf	1ft 8in	Inf	0.5
	25	1ft 6in	10	0.48
	15	1ft 6in	5	0.45
	10	1ft 5in	3	0.43
	6	1ft 3in	2.5	0.42
	5	1ft 3in	2	0.4
	4.5	1ft 2in	1.5	0.38

13.8.2 Dove turn-over prism

A 'Dove' prism enables an image to be rotated in-shot. The image is always upside down or reversed right-to-left.

Cannot be used with lenses wider than 85mm on the 35mm Academy format.



DOVE TURN-OVER PRISM

13.8.3 Image intensifier

Image Intensfiers are developed from 'night-sight' military and security devices which amplify light a thousand or more times, making it possible to expose film even by light of the (celestial) stars.

Used in front of a camera lens they give a greenish image of low resoultion. Mainly used for news and documentary filming.

For feature film production an image intensifier may be incorporated into a camera viewfinder as an aid to setting up a large night crowd scene without the need to switch on all the filming lights.

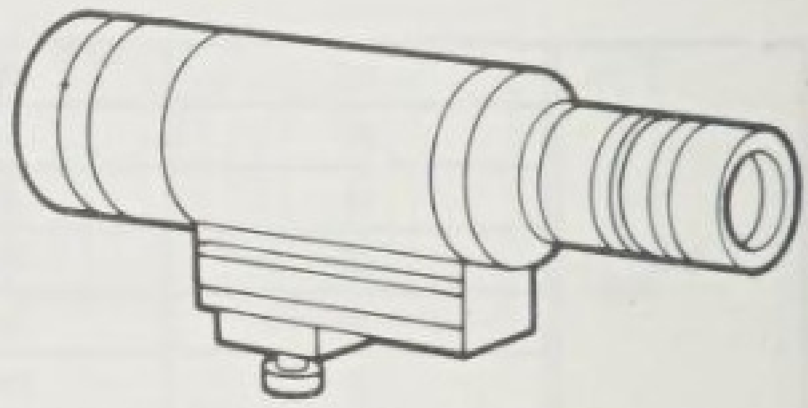


IMAGE INTENSIFIER

13.8.4 Image stabilizer

Image stabilizers are usually either two optical flats separated by a transparent liquid of the same refractive index which form an adjustable prism or two mirrors in the optical path. In either case a sensitive gyroscope adjusts one or both of the elements to optically correct for any sudden deviation of the camera from the optical axis. Thus if the camera is jogged so that it tilts up a little, either the optical flats or the mirrors will be moved out of parallel to bend the light rays back to their original path.

Particularly useful when the camera has to be used on an unstable platform, as filming hand held on horse-back or using a long focal length lens in high wind conditions.

Three drawbacks to either system are that it is difficult to deliberately pan or tilt the camera other than very slowly without first switching off the stabilizer, that neither counters twisting movements about the optical axis and that they can only be used with a moderately long lens (75 - 85mm on the 35mm Academy format)

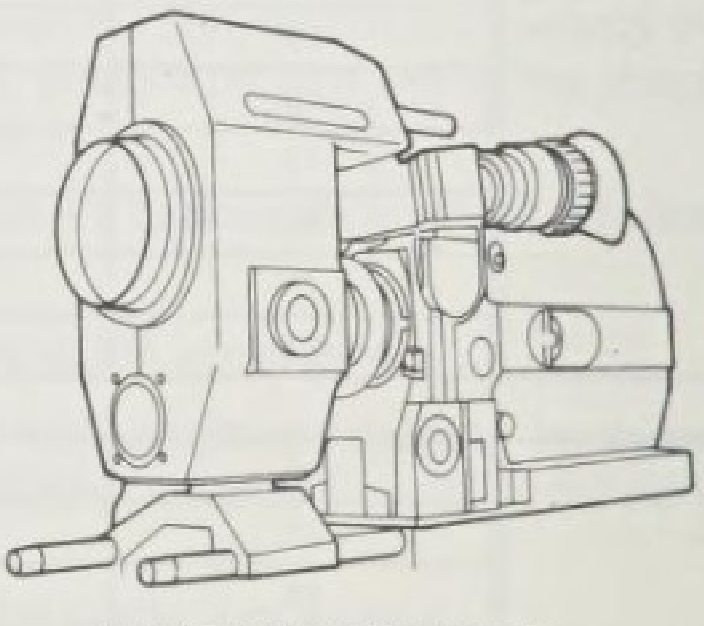


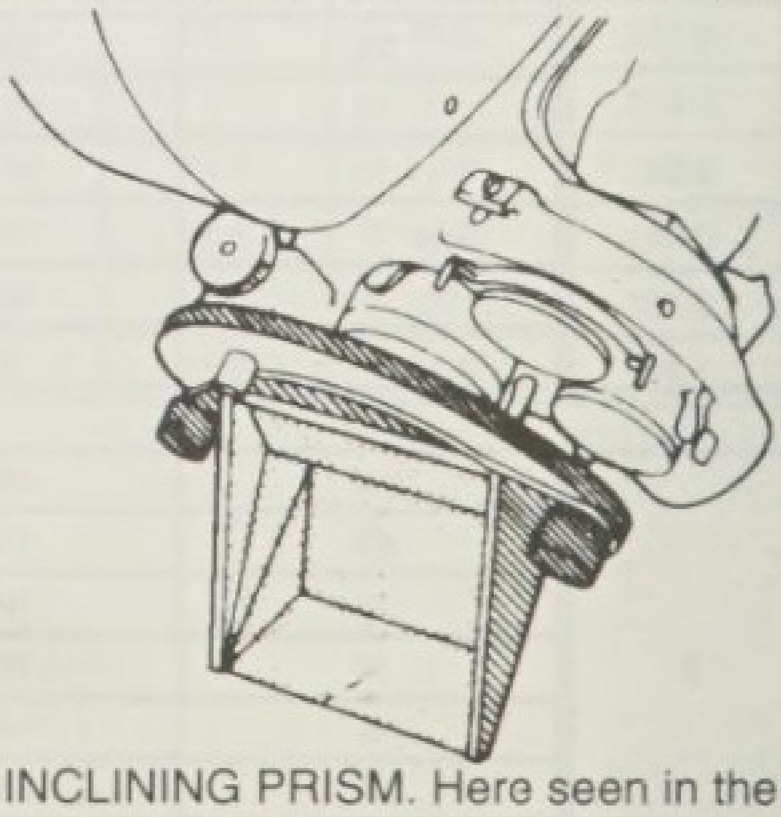
IMAGE STABILIZER

13.8.5 Inclining prism

An 'Inclining prism' can be used in front of a normal to which give an extremely low (or high) angle of view without upsetting the orientation of the image or causing optical distortion or loss of exposure. The effect is like shooting through a mirror but because the light is both refracted internally by the prism and reflected by a mirror coating on the back surface it emerges the correct way round. The 'bend' angle is about 103°.

Used at ground level the effect is as though the camera is placed in a hole in the ground. Used the other way round it can be used to film over a parapet without all of the camera showing or to film over the head of someone standing directly in front of the camera.

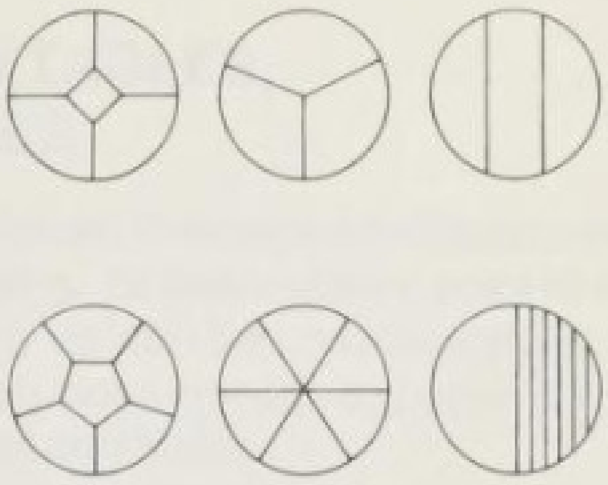
Sometimes called a 'Low angle prism' or 'Bauernfeind' prism (as used with the eye-pieces of astro-telescopes).



INCLINING PRISM. Here seen in the low-angle position.

13.8.6 Multi-image prisms

Multifaceted multi-image prisms may be placed in front of a normal camera lens to create a multiplicity of similar images either radially or in parallel. The radial types are also available with a plain central area so they can be rotated in-shot with a static image in the center of the picture.

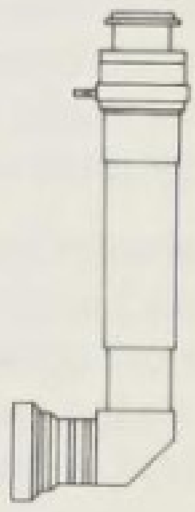


MULTI-IMAGE PRISMS

13.8.7 Periscope and pitching lenses

Periscope lenses are lenses with an extended barrel containig relay lenses, on the end of which the lens is set at 90° to the optical axis. Pitching lenses are similar but incorporate a system whereby the lens can be tilted up and down relative to the lens barrel.

Periscope lenses are used for very low angle camera positions and for shooting models and miniatures where it is advantageous to dip the lens into the 'set'. They are also much used for air-to-air aerial cinematography where it is possible for the lens to protrude through and beneath the body of an aircraft, giving a 360° field of view.

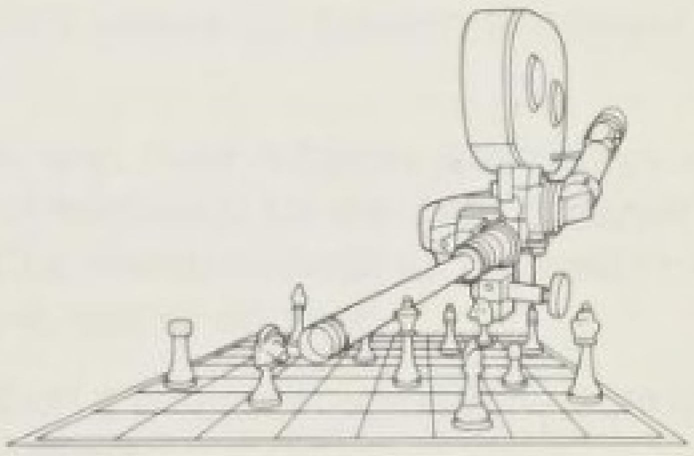


PERISCOPE LENS

13.8.8 Probe lenses

Probe lenses have a long, small diameter, lens barrel with a compact lens at the end. They are useful for table top, miniature and model cinematography making it possible to place the lens in otherwise inaccessible positions.

Also available with a right angle adapter so that it can be used as a periscope type lens.

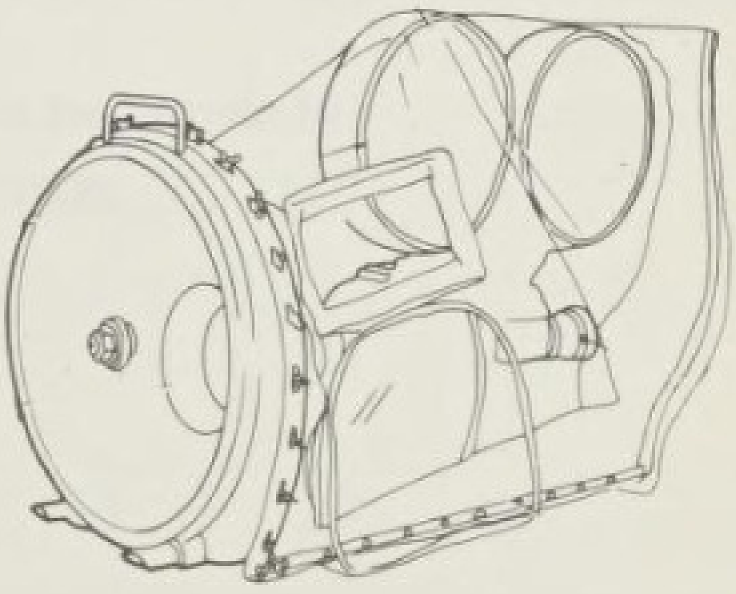


PROBE LENS

13.8.9 Rain deflectors

When shooting in conditions of torrential rain or sea spray not only does the entire camera set-up have to be protected from the elements but the lens must also be kept clear and free of water.

The most effective means, developed for shooting the storm sequence in the film RYAN'S DAUGHTER, is an efficient water-proof cover combined with a high speed spinning glass disk which throws off, by centrifugal force, any water that might otherwise settle on the front of the lens.



SPINNING DISK RAIN DEFLECTOR

13.8.10 Range extenders

'Range extenders' are optical units which can be fitted between a lens and a camera to extend the focal length of a lens. Normally available with 1.4×, 2× and 3× magnification. When used the lens focal length is increased by the magnification factor while the effective aperture is reduced by the square of their magnification. Thus with a 2× range extender a 150mm f/8 lens would become a 300mm f/4. Generally speaking, range extenders should be used with a lens well stopped down.

RANGE EXTENDER

13.9 DEPTH OF FIELD TABLES, FEET AND INCHES

The following Depth of Field tables list near and far distances in acceptable focus covering a range of four circles of confusion, 13 lens focal lengths, 19 intermediate point of focus distances and two numeric systems and are as many as can be conveniently accommodated in a manual such as this. The increments are close enough to permit the user to interpolate focal lengths and distances to suit actual conditions.

As already discussed, many factors influence depth of field calculations and all lenses are different depending upon their design and construction. For all of these reasons calculated depth of field tables can only be approximations. See Section 13.8.

In the final analysis, what is and what is not in acceptable focus is a subjective decision which can be made only after viewing results on the screen and will depend upon many variables. Only when results have been seen, and compared to what the tables forecast, can a suitable circle of confusion on which to make future predictions be determined.

Having seen results or tests and decided which is the near and far distances in acceptable focus for a given lens at a given distance and at a known aperture the Circle of Confusion can be determined by tracing these conditions backwards on the following tables and noting the circle of confusion which best gave those results for that combination of circumstances. This setting may then be used to calculate similar results in the future.

If the suitable circle of confusion is known note the top left hand column (1/500 - 1/2000") and use an aperture setting along that line.

If starting out without making prior tests a circle of confusion of 1/1000" or 1/1400" is likely to be most suitable for most shooting using modern lenses on modern filmstocks and without any diffusion.

To select a 'biased' Depth of Field setting, where, say, near subjects are always more in-focus than far subjects, select a smaller circle of confusion for the near distance and a proportionately larger c of c for the far distance. The same method can be used to cope with lenses which have an inherent optical bias one way or another.

These Depth of Field tables have been generated on a computer spreadsheet program using the formula described in Section 15.6.3 as follows:

> Focal length lens calculations are based on a Fixed Nodal Constant of 2in (50mm).
>
> Where the total depth of field is less than 1ft distances are rounded off to 0.1in, otherwise it is rounded off to the nearest 1in. If the total depth of field is less than 0.1in it is shown as 0.
>
> Distances greater than 50ft are rounded off to the nearest 1ft.
>
> Distances greater than 100ft are shown as >100ft.
>
> Distances less than 6in are shown as 6in.

DEPTH OF FIELD
Feet and Inches

10mm

Circle of Confusion	Aperture										
1/500in				1.4	2	2.8	4	5.6	8	11	16
1/710in			1.4	2	2.8	4	5.6	8	11	16	22
1/1000in		1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in	1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in	2	2.8	4	5.6	8	11	16	22	32		

Hyperfocal dist'	13'	9'	6'	5'	3'	2'	2'	1'	1'	1'	0.5'

Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 6"	2' 4"	2' 2"	1' 11"	1' 8"	1' 5"	1' 2"	1' 0"	0' 10"	0' 8"	0' 6"
	Far	3' 11"	4' 6"	5' 9"	9' 2"	>100'	INF	INF	INF	INF	INF	INF
3'6"	Near	2' 10"	2' 7"	2' 4"	2' 1"	1' 10"	1' 6"	1' 3"	1' 0"	0' 10"	0' 8"	0' 6"
	Far	4' 10"	5' 8"	7' 11"	16' 5"	INF	INF	INF	INF	INF	INF	INF
4'	Near	3' 1"	2' 10"	2' 7"	2' 3"	1' 11"	1' 7"	1' 4"	1' 1"	0' 10"	0' 8"	0' 6"
	Far	5' 10"	7' 2"	11' 0"	39' 9"	INF	INF	INF	INF	INF	INF	INF
4'6"	Near	3' 5"	3' 1"	2' 9"	2' 5"	2' 0"	1' 8"	1' 4"	1' 1"	0' 10"	0' 8"	0' 6"
	Far	6' 11"	8' 11"	15' 9"	INF	INF	INF	INF	INF	INF	INF	INF
5'	Near	3' 8"	3' 4"	2' 11"	2' 6"	2' 1"	1' 9"	1' 5"	1' 1"	0' 10"	0' 8"	0' 6"
	Far	8' 3"	11' 2"	24' 4"	INF	INF	INF	INF	INF	INF	INF	INF
5'6"	Near	3' 11"	3' 7"	3' 1"	2' 8"	2' 2"	1' 9"	1' 5"	1' 2"	0' 10"	0' 8"	0' 7"
	Far	9' 8"	14' 0"	43' 8"	INF	INF	INF	INF	INF	INF	INF	INF
6'	Near	4' 2"	3' 9"	3' 3"	2' 9"	2' 3"	1' 10"	1' 5"	1' 2"	0' 11"	0' 8"	0' 7"
	Far	11' 4"	17' 9"	>100'	INF	INF	INF	INF	INF	INF	INF	INF
6'6"	Near	4' 5"	3' 11"	3' 4"	2' 10"	2' 4"	1' 10"	1' 5"	1' 2"	0' 11"	0' 8"	0' 7"
	Far	13' 3"	23' 0"	INF	INF	INF	INF	INF	INF	INF	INF	INF
7'	Near	4' 8"	4' 1"	3' 6"	2' 11"	2' 4"	1' 11"	1' 6"	1' 2"	0' 11"	0' 8"	0' 7"
	Far	15' 6"	30' 9"	INF	INF	INF	INF	INF	INF	INF	INF	INF
8'	Near	5' 1"	4' 5"	3' 8"	3' 1"	2' 5"	1' 11"	1' 6"	1' 2"	0' 11"	0' 9"	0' 7"
	Far	21' 6"	68'	INF	INF	INF	INF	INF	INF	INF	INF	INF
9'	Near	5' 5"	4' 8"	3' 11"	3' 2"	2' 6"	2' 0"	1' 6"	1' 2"	0' 11"	0' 9"	0' 7"
	Far	30' 7"	>100'	INF	INF	INF	INF	INF	INF	INF	INF	INF
10'	Near	5' 9"	4' 11"	4' 1"	3' 4"	2' 7"	2' 0"	1' 7"	1' 3"	0' 11"	0' 9"	0' 7"
	Far	46' 4"	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
12'	Near	6' 4"	5' 4"	4' 4"	3' 6"	2' 8"	2' 1"	1' 7"	1' 3"	0' 11"	0' 9"	0' 7"
	Far	>100'	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
15'	Near	7' 1"	5' 10"	4' 8"	3' 8"	2' 10"	2' 2"	1' 7"	1' 3"	0' 11"	0' 9"	0' 7"
	Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
20'	Near	8' 0"	6' 6"	5' 0"	3' 11"	2' 11"	2' 3"	1' 8"	1' 3"	0' 11"	0' 9"	0' 7"
	Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
25'	Near	8' 8"	6' 11"	5' 4"	4' 1"	3' 0"	2' 3"	1' 8"	1' 3"	0' 11"	0' 9"	0' 7"
	Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
30'	Near	9' 2"	7' 3"	5' 6"	4' 2"	3' 1"	2' 4"	1' 8"	1' 4"	0' 11"	0' 9"	0' 7"
	Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

17mm

Circle of Confusion		Aperture										
1/500in					1.4	2	2.8	4	5.6	8	11	16
1/710in				1.4	2	2.8	4	5.6	8	11	16	22
1/1000in			1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in		1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		37'	27'	19'	13'	9'	7'	5'	3'	2'	2'	1'
Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 9.6"	2' 8.7"	2' 7.5"	2' 6"	2' 4"	2' 2"	1' 11"	1' 9"	1' 5"	1' 3"	1' 0"
	Far	3' 3.2"	3' 4.6"	3' 6.9"	3' 11"	4' 5"	5' 7"	9' 0"	42' 7"	INF	INF	INF
3'6"	Near	3' 2.7"	3' 1.6"	3' 0"	2' 10"	2' 7"	2' 5"	2' 1"	1' 10"	1' 6"	1' 3"	1' 0"
	Far	3' 10.4	4' 0.4"	4' 4"	4' 9"	5' 8"	7' 7"	15' 9"	INF	INF	INF	INF
4'	Near	3' 7.7"	3' 6"	3' 4"	3' 2"	2' 11"	2' 7"	2' 3"	2' 0"	1' 7"	1' 4"	1' 1"
	Far	4' 5.8"	4' 9"	5' 1"	5' 9"	7' 1"	10' 5"	36' 0"	INF	INF	INF	INF
4'6"	Near	4' 1"	3' 11"	3' 8"	3' 5"	3' 2"	2' 10"	2' 5"	2' 1"	1' 8"	1' 5"	1' 1"
	Far	5' 1"	5' 5"	5' 11"	6' 10"	8' 10"	14' 7"	INF	INF	INF	INF	INF
5'	Near	4' 5"	4' 3"	4' 0"	3' 9"	3' 4"	3' 0"	2' 6"	2' 2"	1' 9"	1' 5"	1' 1"
	Far	5' 9"	6' 2"	6' 10"	8' 1"	11' 0"	21' 8"	INF	INF	INF	INF	INF
5'6"	Near	4' 10"	4' 7"	4' 4"	4' 0"	3' 7"	3' 2"	2' 8"	2' 3"	1' 9"	1' 5"	1' 1"
	Far	6' 5"	6' 11"	7' 10"	9' 5"	13' 9"	35' 9"	INF	INF	INF	INF	INF
6'	Near	5' 3"	4' 11"	4' 7"	4' 3"	3' 9"	3' 3"	2' 9"	2' 4"	1' 10"	1' 6"	1' 2"
	Far	7' 2"	7' 9"	8' 11"	11' 0"	17' 4"	78'	INF	INF	INF	INF	INF
6'6"	Near	5' 7"	5' 3"	4' 11"	4' 6"	3' 11"	3' 5"	2' 10"	2' 5"	1' 10"	1' 6"	1' 2"
	Far	7' 11"	8' 7"	10' 0"	12' 10"	22' 4"	INF	INF	INF	INF	INF	INF
7'	Near	5' 11"	5' 7"	5' 2"	4' 8"	4' 1"	3' 6"	2' 11"	2' 5"	1' 11"	1' 6"	1' 2"
	Far	8' 7"	9' 6"	11' 3"	14' 11"	29' 7"	INF	INF	INF	INF	INF	INF
8'	Near	6' 8"	6' 3"	5' 8"	5' 1"	4' 5"	3' 9"	3' 1"	2' 6"	2' 0"	1' 7"	1' 2"
	Far	10' 2"	11' 6"	14' 1"	20' 5"	62'	INF	INF	INF	INF	INF	INF
9'	Near	7' 4"	6' 10"	6' 2"	5' 6"	4' 8"	4' 0"	3' 3"	2' 7"	2' 0"	1' 7"	1' 2"
	Far	11' 11"	13' 8"	17' 6"	28' 5"	>100'	INF	INF	INF	INF	INF	INF
10'	Near	7' 11"	7' 4"	6' 7"	5' 10"	4' 11"	4' 2"	3' 4"	2' 8"	2' 1"	1' 7"	1' 3"
	Far	13' 8"	16' 1"	21' 9"	41' 7"	INF	INF	INF	INF	INF	INF	INF
12'	Near	9' 2"	8' 4"	7' 5"	6' 5"	5' 5"	4' 5"	3' 6"	2' 10"	2' 1"	1' 8"	1' 3"
	Far	17' 9"	21' 11"	34' 2"	>100'	INF	INF	INF	INF	INF	INF	INF
15'	Near	10' 9"	9' 8"	8' 5"	7' 2"	5' 11"	4' 9"	3' 9"	2' 11"	2' 2"	1' 8"	1' 3"
	Far	25' 2"	34' 7"	79'	INF	INF	INF	INF	INF	INF	INF	INF
20'	Near	13' 1"	11' 6"	9' 9"	8' 2"	6' 6"	5' 2"	3' 11"	3' 1"	2' 3"	1' 9"	1' 3"
	Far	43' 4"	81'	INF	INF	INF	INF	INF	INF	INF	INF	INF
25'	Near	15' 1"	13' 0"	10' 10"	8' 10"	6' 11"	5' 5"	4' 1"	3' 2"	2' 4"	1' 9"	1' 3"
	Far	76'	>100'	INF	INF	INF	INF	INF	INF	INF	INF	INF
30'	Near	16' 9"	14' 3"	11' 8"	9' 5"	7' 3"	5' 7"	4' 2"	3' 3"	2' 4"	1' 9"	1' 3"
	Far	>100'	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
50'	Near	21' 6"	17' 6"	13' 9"	10' 8"	8' 0"	6' 1"	4' 5"	3' 4"	2' 5"	1' 10"	1' 4"
	Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

20mm

Circle of Confusion		Aperture										
1/500in					1.4	2	2.8	4	5.6	8	11	16
1/710in				1.4	2	2.8	4	5.6	8	11	16	22
1/1000in			1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in		1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		52'	37'	26'	18'	13'	9'	6'	5'	3'	2'	2'
Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 10"	2' 9.6"	2' 8.6"	2' 7.5"	2' 6"	2' 4"	2' 2"	1' 11"	1' 8"	1' 5"	1' 2"
	Far	3' 2.2"	3' 3.2"	3' 4.7"	3' 7.0"	3' 11"	4' 6"	5' 9"	8' 10"	>100'	INF	INF
3'6"	Near	3' 3.6"	3' 2.7"	3' 1.4"	3' 0"	2' 10"	2' 7"	2' 4"	2' 1"	1' 10"	1' 7"	1' 3"
	Far	3' 9.1"	3' 10"	4' 0.6"	4' 4"	4' 10"	5' 8"	7' 11"	15' 4"	INF	INF	INF
4'	Near	3' 8.8"	3' 7.7"	3' 6"	3' 4"	3' 1"	2' 10"	2' 7"	2' 3"	1' 11"	1' 7"	1' 4"
	Far	4' 4.0"	4' 5.9"	4' 9"	5' 1"	5' 10"	7' 2"	11' 0"	34' 1"	INF	INF	INF
4'6"	Near	4' 2.0"	4' 1"	3' 11"	3' 8"	3' 5"	3' 1"	2' 9"	2' 5"	2' 0"	1' 8"	1' 4"
	Far	4' 11"	5' 2"	5' 5"	6' 0"	6' 11"	8' 11"	15' 9"	>100'	INF	INF	INF
5'	Near	4' 7.0"	4' 5"	4' 3"	4' 0"	3' 8"	3' 4"	2' 11"	2' 7"	2' 1"	1' 9"	1' 5"
	Far	5' 6.4"	5' 9"	6' 2"	6' 11"	8' 3"	11' 2"	24' 4"	INF	INF	INF	INF
5'6"	Near	5' 0"	4' 10"	4' 7"	4' 4"	3' 11"	3' 7"	3' 1"	2' 8"	2' 2"	1' 10"	1' 5"
	Far	6' 2"	6' 6"	7' 0"	7' 10"	9' 8"	14' 0"	43' 8"	INF	INF	INF	INF
6'	Near	5' 5"	5' 2"	4' 11"	4' 7"	4' 2"	3' 9"	3' 3"	2' 9"	2' 3"	1' 10"	1' 5"
	Far	6' 9"	7' 2"	7' 10"	8' 11"	11' 4"	17' 9"	>100'	INF	INF	INF	INF
6'6"	Near	5' 10"	5' 7"	5' 3"	4' 11"	4' 5"	3' 11"	3' 4"	2' 10"	2' 4"	1' 11"	1' 5"
	Far	7' 5"	7' 11"	8' 8"	10' 1"	13' 3"	23' 0"	INF	INF	INF	INF	INF
7'	Near	6' 2"	5' 11"	5' 7"	5' 2"	4' 8"	4' 1"	3' 6"	2' 11"	2' 4"	1' 11"	1' 6"
	Far	8' 1"	8' 8"	9' 7"	11' 4"	15' 6"	30' 9"	INF	INF	INF	INF	INF
8'	Near	7' 0"	6' 8"	6' 2"	5' 8"	5' 1"	4' 5"	3' 8"	3' 1"	2' 5"	2' 0"	1' 6"
	Far	9' 6"	10' 3"	11' 7"	14' 3"	21' 6"	68'	INF	INF	INF	INF	INF
9'	Near	7' 9"	7' 4"	6' 9"	6' 2"	5' 5"	4' 8"	3' 11"	3' 3"	2' 6"	2' 0"	1' 6"
	Far	10' 11"	11' 11"	13' 10"	17' 9"	30' 7"	>100'	INF	INF	INF	INF	INF
10'	Near	8' 5"	7' 11"	7' 3"	6' 7"	5' 9"	4' 11"	4' 1"	3' 4"	2' 7"	2' 1"	1' 7"
	Far	12' 5"	13' 9"	16' 5"	22' 1"	46' 4"	INF	INF	INF	INF	INF	INF
12'	Near	9' 10"	9' 2"	8' 3"	7' 5"	6' 4"	5' 4"	4' 4"	3' 6"	2' 8"	2' 2"	1' 7"
	Far	15' 8"	17' 10"	22' 6"	34' 11"	>100'	INF	INF	INF	INF	INF	INF
15'	Near	11' 8"	10' 9"	9' 7"	8' 5"	7' 1"	5' 10"	4' 8"	3' 9"	2' 10"	2' 2"	1' 7"
	Far	21' 2"	25' 4"	36' 1"	83'	INF	INF	INF	INF	INF	INF	INF
20'	Near	14' 6"	13' 1"	11' 5"	9' 9"	8' 0"	6' 6"	5' 0"	4' 0"	2' 11"	2' 3"	1' 8"
	Far	32' 8"	43' 11"	90'	INF	INF	INF	INF	INF	INF	INF	INF
25'	Near	16' 11"	15' 0"	12' 10"	10' 9"	8' 8"	6' 11"	5' 4"	4' 1"	3' 0"	2' 4"	1' 8"
	Far	48' 7"	78'	>100'	INF	INF	INF	INF	INF	INF	INF	INF
30'	Near	19' 1"	16' 8"	14' 0"	11' 7"	9' 2"	7' 3"	5' 6"	4' 3"	3' 1"	2' 4"	1' 8"
	Far	71'	>100'	INF	INF	INF	INF	INF	INF	INF	INF	INF
50'	Near	25' 6"	21' 4"	17' 2"	13' 8"	10' 5"	7' 11"	5' 11"	4' 6"	3' 2"	2' 5"	1' 9"
	Far	>100'	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

25mm

Circle of Confusion		Aperture										
1/500in					1.4	2	2.8	4	5.6	8	11	16
1/710in				1.4	2	2.8	4	5.6	8	11	16	22
1/1000in			1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in		1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		81'	58'	40'	29'	20'	14'	10'	7'	5'	4'	3'
Focus distance		Extreme distance in acceptable focus										
3’	Near	2' 11"	2' 10"	2' 9.8"	2' 9.0"	2' 7.8"	2' 6"	2' 5"	2' 3"	1' 0"	1' 9"	1' 6"
	Far	3' 1.4"	3' 2.0"	3' 2.9"	3' 4.2"	3' 6.3"	3' 10"	4' 4"	5' 2"	7' 9"	20' 10"	INF
3’6"	Near	3' 4.4"	3' 3.8"	3' 2.9"	3' 1.9"	3' 0"	2' 10"	2' 8"	2' 6"	2' 2"	1' 11"	1' 7"
	Far	3' 7.9"	3' 8.7"	3' 10"	4' 0"	4' 3"	4' 8"	5' 5"	6' 10"	12' 4"	>100'	INF
4’	Near	3' 9.9"	3' 9.1"	3' 8.0"	3' 7"	3' 5"	3' 2"	2' 11"	2' 8"	2' 4"	2' 0"	1' 8"
	Far	4' 2.5"	4' 3.6"	4' 5.3"	4' 8"	5' 0"	5' 7"	6' 8"	9' 0"	22' 2"	INF	INF
4’6"	Near	4' 3.4"	4' 2.4"	4' 1.0"	3' 11"	3' 9"	3' 6"	3' 2"	2' 11"	2' 6"	2' 2"	1' 9"
	Far	4' 9.2"	4' 11"	5' 0.8"	5' 4"	5' 10"	6' 7"	8' 3"	12' 1"	57'	INF	INF
5’	Near	4' 8.7"	4' 7.5"	4' 6"	4' 4"	4' 1"	3' 9"	3' 5"	3' 1"	2' 8"	2' 3"	1' 10"
	Far	5' 4.0"	5' 5.7"	5' 9"	6' 1"	6' 8"	7' 8"	10' 1"	16' 6"	INF	INF	INF
5’6"	Near	5' 2.0"	5' 1"	4' 11"	4' 8"	4' 5"	4' 1"	3' 8"	3' 3"	2' 9"	2' 4"	1' 11"
	Far	5' 11"	6' 1"	6' 4"	6' 10"	7' 7"	8' 11"	12' 4"	23' 7"	INF	INF	INF
6’	Near	5' 7.3"	5' 6"	5' 3"	5' 0"	4' 8"	4' 4"	3' 10"	3' 5"	2' 10"	2' 5"	1' 11"
	Far	6' 5.8"	6' 8"	7' 1"	7' 7"	8' 7"	10' 4"	15' 2"	36' 8"	INF	INF	INF
6’6"	Near	6' 0"	5' 10"	5' 8"	5' 4"	5' 0"	4' 7"	4' 1"	3' 7"	3' 0"	2' 6"	2' 0"
	Far	7' 1"	7' 4"	7' 9"	8' 5"	9' 7"	11' 11"	18' 10"	69'	INF	INF	INF
7’	Near	6' 6"	6' 3"	6' 0"	5' 8"	5' 3"	4' 10"	4' 3"	3' 8"	3' 1"	2' 7"	2' 0"
	Far	7' 8"	8' 0"	8' 6"	9' 3"	10' 9"	13' 9"	23' 9"	>100'	INF	INF	INF
8’	Near	7' 4"	7' 1"	6' 9"	6' 4"	5' 10"	5' 3"	4' 7"	3' 11"	3' 3"	2' 8"	2' 1"
	Far	8' 11"	9' 4"	10' 0"	11' 1"	13' 4"	18' 3"	41' 3"	INF	INF	INF	INF
9’	Near	8' 2"	7' 10"	7' 5"	6' 11"	6' 4"	5' 8"	4' 11"	4' 2"	3' 5"	2' 9"	2' 2"
	Far	10' 2"	10' 8"	11' 7"	13' 1"	16' 4"	24' 5"	96'	INF	INF	INF	INF
10’	Near	8' 11"	8' 7"	8' 1"	7' 6"	6' 9"	6' 0"	5' 2"	4' 4"	3' 6"	2' 10"	2' 2"
	Far	11' 5"	12' 1"	13' 4"	15' 4"	20' 0"	33' 6"	INF	INF	INF	INF	INF
12’	Near	10' 6"	X10' 0"	9' 4"	8' 7"	7' 8"	6' 8"	5' 7"	4' 8"	3' 8"	3' 0"	2' 3"
	Far	14' 1"	15' 2"	17' 1"	20' 8"	30' 0"	76'	INF	INF	INF	INF	INF
15’	Near	12' 8"	12' 0"	11' 0"	10' 0"	8' 9"	7' 6"	6' 2"	5' 1"	3' 11"	3' 1"	2' 4"
	Far	18' 5"	20' 4"	23' 11"	31' 6"	59'	INF	INF	INF	INF	INF	INF
20’	Near	16' 1"	14' 11"	13' 6"	11' 11"	10' 2"	8' 6"	6' 10"	5' 6"	4' 2"	3' 3"	2' 5"
	Far	26' 7"	30' 8"	39' 10"	66'	>100'	INF	INF	INF	INF	INF	INF
25’	Near	19' 2"	17' 6"	15' 6"	13' 6"	11' 4"	9' 3"	7' 4"	5' 10"	4' 4"	3' 4"	2' 5"
	Far	36' 3"	44' 3"	66'	>100'	INF	INF	INF	INF	INF	INF	INF
30’	Near	21' 11"	19' 10"	17' 4"	14' 10"	12' 2"	9' 11"	7' 8"	6' 1"	4' 6"	3' 5"	2' 6"
	Far	47' 10"	62'	>100'	INF	INF	INF	INF	INF	INF	INF	INF
50’	Near	31' 0"	26' 11"	22' 6"	18' 5"	14' 6"	11' 4"	8' 7"	6' 7"	4' 9"	3' 7"	2' 7"
	Far	>100'	>100'	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

30mm

Circle of Confusion	Aperture										
1/500in				1.4	2	2.8	4	5.6	8	11	16
1/710in			1.4	2	2.8	4	5.6	8	11	16	22
1/1000in		1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in	1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	116'	83'	58'	42'	29'	21'	15'	11'	7'	5'	4'

Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 11.2	2' 10.9	2' 10.4	2' 9.8"	2' 9.0"	2' 7.9"	2' 6"	2' 5"	2' 2"	2' 0"	1' 9"
	Far	3' 1.0"	3' 1.3"	3' 2.0"	3' 2.8"	3' 4.2"	3' 6.1"	3' 9"	4' 3"	5' 2"	7' 3"	22' 3"
3'6"	Near	3' 4.9"	3' 4.5"	3' 3.8"	3' 3.0"	3' 1.9"	3' 0"	2' 11"	2' 8"	2' 5"	2' 3"	1' 11"
	Far	3' 7.3"	3' 7.8"	3' 8.7"	3' 9.9"	3' 11.8	4' 3"	4' 7"	5' 3"	6' 11"	11' 1"	INF
4'	Near	3' 10.5	3' 10.0	3' 9.2"	3' 8.1"	3' 7"	3' 5"	3' 2"	3' 0"	2' 8"	2' 5"	2' 0"
	Far	4' 1.7"	4' 2.4"	4' 3.6"	4' 5.1"	4' 8"	5' 0"	5' 6"	6' 6"	9' 2"	18' 4"	INF
4'6"	Near	4' 4.1"	4' 3.4"	4' 2.4"	4' 1.1"	3' 11"	3' 9"	3' 6"	3' 3"	2' 11"	2' 7"	2' 2"
	Far	4' 8.2"	4' 9.1"	4' 10.5"	5' 0.6"	5' 4"	5' 9"	6' 7"	7' 11"	12' 3"	37' 3"	INF
5'	Near	4' 9.7"	4' 8.8"	4' 7.5"	4' 6"	4' 4"	4' 1"	3' 10"	3' 6"	3' 1"	2' 8"	2' 3"
	Far	5' 2.7"	5' 3.8"	5' 5.7"	5' 8"	6' 1"	6' 7"	7' 8"	9' 7"	16' 11"	>100'	INF
5'6"	Near	5' 3.2"	5' 2.1"	5' 1"	4' 11"	4' 8"	4' 5"	4' 1"	3' 9"	3' 3"	2' 10"	2' 4"
	Far	5' 9.3"	5' 10.7	6' 1"	6' 4"	6' 10"	7' 6"	8' 11"	11' 8"	24' 5"	INF	INF
6'	Near	5' 8.7"	5' 7.4"	5' 6"	5' 3"	5' 0"	4' 9"	4' 4"	3' 11"	3' 5"	2' 11"	2' 5"
	Far	6' 3.9"	6' 5.6"	6' 8"	7' 0"	7' 7"	8' 6"	10' 4"	14' 2"	38' 9"	INF	INF
6'6"	Near	6' 2.1"	6' 1"	5' 11"	5' 8"	5' 4"	5' 0"	4' 7"	4' 2"	3' 7"	3' 1"	2' 6"
	Far	6' 10.6	7' 1"	7' 4"	7' 9"	8' 5"	9' 6"	11' 10"	17' 4"	76'	INF	INF
7'	Near	6' 7.4"	6' 6"	6' 3"	6' 0"	5' 8"	5' 4"	4' 10"	4' 4"	3' 8"	3' 2"	2' 6"
	Far	7' 5.4"	7' 8"	8' 0"	8' 5"	9' 3"	10' 7"	13' 8"	21' 5"	>100'	INF	INF
8'	Near	7' 6"	7' 4"	7' 1"	6' 9"	6' 4"	5' 10"	5' 3"	4' 8"	3' 11"	3' 4"	2' 8"
	Far	8' 7"	8' 10"	9' 3"	9' 11"	11' 1"	13' 1"	18' 1"	34' 8"	INF	INF	INF
9'	Near	8' 5"	8' 2"	7' 10"	7' 5"	6' 11"	6' 4"	5' 8"	5' 0"	4' 2"	3' 6"	2' 9"
	Far	9' 9"	10' 1"	10' 8"	11' 6"	13' 1"	16' 0"	24' 1"	66'	INF	INF	INF
10'	Near	9' 3"	9' 0"	8' 7"	8' 1"	7' 6"	6' 10"	6' 0"	5' 3"	4' 4"	3' 7"	2' 10"
	Far	10' 11"	11' 4"	12' 1"	13' 2"	15' 3"	19' 5"	32' 11"	>100'	INF	INF	INF
12'	Near	10' 11"	10' 6"	10' 0"	9' 5"	8' 7"	7' 8"	6' 8"	5' 9"	4' 8"	3' 10"	2' 11"
	Far	13' 5"	14' 0"	15' 2"	16' 11"	20' 6"	28' 9"	72'	INF	INF	INF	INF
15'	Near	13' 4"	12' 9"	12' 0"	11' 1"	10' 0"	8' 10"	7' 6"	6' 4"	5' 1"	4' 1"	3' 1"
	Far	17' 3"	18' 4"	20' 3"	23' 6"	31' 2"	55'	INF	INF	INF	INF	INF
20'	Near	17' 1"	16' 2"	14' 11"	13' 7"	11' 11"	10' 4"	8' 7"	7' 1"	5' 6"	4' 4"	3' 3"
	Far	24' 2"	26' 4"	30' 6"	38' 9"	64'	>100'	INF	INF	INF	INF	INF
25'	Near	20' 8"	19' 3"	17' 7"	15' 8"	13' 7"	11' 6"	9' 4"	7' 7"	5' 9"	4' 6"	3' 4"
	Far	31' 10"	35' 10"	44' 0"	63'	>100'	INF	INF	INF	INF	INF	INF
30'	Near	23' 11"	22' 1"	19' 11"	17' 6"	14' 11"	12' 5"	9' 11"	8' 0"	6' 0"	4' 8"	3' 5"
	Far	40' 5"	47' 0"	62'	>100'	INF	INF	INF	INF	INF	INF	INF
50'	Near	35' 1"	31' 4"	27' 0"	22' 10"	18' 6"	14' 10"	11' 5"	8' 11"	6' 6"	4' 11"	3' 7"
	Far	87'	>100'	>100'	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

35mm

Circle of Confusion		Aperture										
1/500in					1.4	2	2.8	4	5.6	8	11	16
1/710in				1.4	2	2.8	4	5.6	8	11	16	22
1/1000in			1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in		1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		158'	113'	79'	57'	40'	28'	20'	14'	10'	7'	5'
Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 11.4	2' 11.2	2' 10.8	2' 10.4	2' 9.7"	2' 8.9"	2' 7.7"	2' 6"	2' 4"	2' 2"	2' 0"
	Far	3' 0.7"	3' 1.0"	3' 1.4"	3' 2.0"	3' 3.0"	3' 4.3"	3' 6.5"	3' 10"	4' 4"	5' 3"	8' 1"
3'6"	Near	3' 5.2"	3' 4.9"	3' 4.4"	3' 3.8"	3' 2.9"	3' 1.8"	3' 0"	2' 10"	2' 8"	2' 5"	2' 2"
	Far	3' 6.9"	3' 7.3"	3' 7.9"	3' 8.8"	3' 10.1	3' 12.0	4' 3"	4' 8"	5' 6"	7' 0"	13' 1"
4'	Near	3' 10.9	3' 10.5	3' 9.9"	3' 9.1"	3' 7.9"	3' 7"	3' 5"	3' 2"	2' 11"	2' 8"	2' 4"
	Far	4' 1.2"	4' 1.8"	4' 2.6"	4' 3.7"	4' 5.4"	4' 8"	5' 0"	5' 7"	6' 9"	9' 3"	24' 6"
4'6"	Near	4' 4.6"	4' 4.1"	4' 3.3"	4' 2.3"	4' 1"	3' 11"	3' 9"	3' 6"	3' 2"	2' 10"	2' 6"
	Far	4' 7.6"	4' 8.2"	4' 9.3"	4' 10.7	5' 1"	5' 4"	5' 10"	6' 7"	8' 4"	12' 6"	77'
5'	Near	4' 10.3	4' 9.6"	4' 8.7"	4' 7.4"	4' 6"	4' 4"	4' 1"	3' 9"	3' 5"	3' 1"	2' 7"
	Far	5' 2.0"	5' 2.8"	5' 4.1"	5' 5.8"	5' 9"	6' 1"	6' 9"	7' 9"	10' 3"	17' 4"	INF
5'6"	Near	5' 3.9"	5' 3.1"	5' 2.0"	5' 0"	4' 10"	4' 8"	4' 4"	4' 1"	3' 8"	3' 3"	2' 9"
	Far	5' 8.4"	5' 9.4"	5' 10.9	6' 1"	6' 5"	6' 10"	7' 8"	9' 0"	12' 8"	25' 4"	INF
6'	Near	5' 9.5"	5' 8.6"	5' 7.2"	5' 5"	5' 3"	5' 0"	4' 8"	4' 4"	3' 10"	3' 5"	2' 10"
	Far	6' 2.8"	6' 4.0"	6' 5.9"	6' 9"	7' 1"	7' 8"	8' 8"	10' 5"	15' 8"	41' 1"	INF
6'6"	Near	6' 3.1"	6' 2.0"	6' 0"	5' 10"	5' 8"	5' 4"	5' 0"	4' 7"	4' 0"	3' 6"	2' 11"
	Far	6' 9.3"	6' 10.8	7' 1"	7' 4"	7' 9"	8' 5"	9' 9"	12' 0"	19' 7"	86'	INF
7'	Near	6' 8.6"	6' 7.3"	6' 5"	6' 3"	6' 0"	5' 8"	5' 3"	4' 10"	4' 2"	3' 8"	3' 0"
	Far	7' 3.9"	7' 5.6"	7' 8"	8' 0"	8' 6"	9' 4"	10' 11"	13' 9"	25' 0"	>100'	INF
8'	Near	7' 7.6"	7' 6"	7' 4"	7' 1"	6' 8"	6' 4"	5' 9"	5' 3"	4' 6"	3' 11"	3' 2"
	Far	8' 5.1"	8' 7"	8' 11"	9' 4"	10' 0"	11' 2"	13' 6"	18' 3"	45' 2"	INF	INF
9'	Near	8' 6"	8' 4"	8' 1"	7' 10"	7' 5"	6' 11"	6' 3"	5' 8"	4' 10"	4' 2"	3' 4"
	Far	9' 7"	9' 9"	10' 2"	10' 9"	11' 8"	13' 3"	16' 8"	24' 6"	>100'	INF	INF
10'	Near	9' 5"	9' 3"	8' 11"	8' 7"	8' 1"	7' 6"	6' 9"	6' 0"	5' 1"	4' 4"	3' 5"
	Far	10' 8"	11' 0"	11' 5"	12' 2"	13' 5"	15' 6"	20' 5"	33' 8"	INF	INF	INF
12'	Near	11' 2"	10' 11"	10' 6"	9' 11"	9' 3"	8' 6"	7' 7"	6' 8"	5' 7"	4' 8"	3' 8"
	Far	13' 0"	13' 5"	14' 2"	15' 3"	17' 3"	20' 11"	30' 11"	76'	INF	INF	INF
15'	Near	13' 9"	13' 3"	12' 8"	11' 11"	10' 11"	9' 11"	8' 8"	7' 6"	6' 1"	5' 0"	3' 11"
	Far	16' 7"	17' 4"	18' 6"	20' 5"	24' 3"	32' 2"	63'	INF	INF	INF	INF
20'	Near	17' 9"	17' 0"	16' 0"	14' 10"	13' 5"	11' 10"	10' 1"	8' 6"	6' 9"	5' 5"	4' 1"
	Far	22' 11"	24' 4"	26' 9"	31' 0"	40' 8"	69'	INF	INF	INF	INF	INF
25'	Near	21' 8"	20' 6"	19' 1"	17' 5"	15' 5"	13' 5"	11' 2"	9' 3"	7' 3"	5' 9"	4' 3"
	Far	29' 8"	32' 1"	36' 7"	44' 11"	68'	>100'	INF	INF	INF	INF	INF
30'	Near	25' 3"	23' 9"	21' 10"	19' 8"	17' 2"	14' 8"	12' 1"	9' 10"	7' 7"	6' 0"	4' 5"
	Far	37' 0"	40' 10"	48' 5"	64'	>100'	INF	INF	INF	INF	INF	INF
50'	Near	38' 1"	34' 9"	30' 9"	26' 8"	22' 3"	18' 2"	14' 4"	11' 4"	8' 5"	6' 5"	4' 8"
	Far	73'	89'	>100'	>100'	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

40mm

Circle of Confusion		Aperture										
1/500in					1.4	2	2.8	4	5.6	8	11	16
1/710in				1.4	2	2.8	4	5.6	8	11	16	22
1/1000in			1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in		1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		207'	148'	103'	74'	52'	37'	26'	19'	13'	9'	6'
Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 11.5	2' 11.4	2' 11.1	2' 10.7	2' 10.2	2' 9.6"	2' 8.6"	2' 7.5"	2' 6"	2' 4"	2' 2"
	Far	3' 0.5"	3' 0.7"	3' 1.1"	3' 1.5"	3' 2.2"	3' 3.2"	3' 4.7"	3' 6.9"	3' 11"	4' 5"	5' 9"
3'6"	Near	3' 5.4"	3' 5.1"	3' 4.8"	3' 4.3"	3' 3.6"	3' 2.7"	3' 1.4"	3' 0"	2' 10"	2' 8"	2' 4"
	Far	3' 6.7"	3' 7.0"	3' 7.5"	3' 8.1"	3' 9.1"	3' 10.4	4' 0.6"	4' 4"	4' 10"	5' 8"	7' 11"
4'	Near	3' 11.2	3' 10.8	3' 10.4	3' 9.7"	3' 8.8"	3' 7.7"	3' 6"	3' 4"	3' 1"	2' 11"	2' 7"
	Far	4' 0.9"	4' 1.3"	4' 1.9"	4' 2.8"	4' 4.0"	4' 5.9"	4' 9"	5' 1"	5' 10"	7' 1"	11' 0"
4'6"	Near	4' 4.9"	4' 4.5"	4' 3.9"	4' 3.1"	4' 2.0"	4' 1"	3' 11"	3' 8"	3' 5"	3' 2"	2' 9"
	Far	4' 7.2"	4' 7.7"	4' 8.5"	4' 9.5"	4' 11.2	5' 2"	5' 5"	5' 11"	6' 11"	8' 9"	15' 9"
5'	Near	4' 10.7	4' 10.2	4' 9.4"	4' 8.4"	4' 7.0"	4' 5"	4' 3"	4' 0"	3' 8"	3' 4"	2' 11"
	Far	5' 1.5"	5' 2.1"	5' 3.1"	5' 4.4"	5' 6.4"	5' 9"	6' 2"	6' 10"	8' 3"	10' 11"	24' 4"
5'6"	Near	5' 4.4"	5' 3.8"	5' 2.9"	5' 1.7"	5' 0"	4' 10"	4' 7"	4' 4"	3' 11"	3' 7"	3' 1"
	Far	5' 7.8"	5' 8.6"	5' 9.7"	5' 11.3	6' 2"	6' 6"	7' 0"	7' 10"	9' 8"	13' 7"	43' 8"
6'	Near	5' 10.1	5' 9.3"	5' 8.3"	5' 6.9"	5' 5"	5' 2"	4' 11"	4' 7"	4' 2"	3' 9"	3' 3"
	Far	6' 2.2"	6' 3.1"	6' 4.4"	6' 6.4"	6' 9"	7' 2"	7' 10"	8' 10"	11' 4"	17' 2"	>100'
6'6"	Near	6' 3.7"	6' 2.9"	6' 1.6"	6' 0"	5' 10"	5' 7"	5' 3"	4' 11"	4' 5"	3' 11"	3' 4"
	Far	6' 8.5"	6' 9.6"	6' 11.2	7' 2"	7' 5"	7' 11"	8' 8"	10' 0"	13' 3"	22' 0"	INF
7'	Near	6' 9.4"	6' 8.4"	6' 6.9"	6' 5"	6' 2"	5' 11"	5' 7"	5' 2"	4' 8"	4' 1"	3' 6"
	Far	7' 2.9"	7' 4.2"	7' 6.1"	7' 9"	8' 1"	8' 8"	9' 7"	11' 3"	15' 6"	29' 0"	INF
8'	Near	7' 8.6"	7' 7.3"	7' 5"	7' 3"	7' 0"	6' 8"	6' 2"	5' 8"	5' 1"	4' 5"	3' 8"
	Far	8' 3.9"	8' 5.5"	8' 8"	9' 0"	9' 6"	10' 3"	11' 7"	14' 0"	21' 6"	60'	INF
9'	Near	8' 7.7"	8' 6"	8' 4"	8' 1"	7' 9"	7' 4"	6' 9"	6' 2"	5' 5"	4' 9"	3' 11"
	Far	9' 4.9"	9' 7"	9' 10"	10' 3"	10' 11"	11' 11"	13' 10"	17' 5"	30' 7"	>100'	INF
10'	Near	9' 7"	9' 5"	9' 2"	8' 10"	8' 5"	7' 11"	7' 3"	6' 7"	5' 9"	5' 0"	4' 1"
	Far	10' 6"	10' 9"	11' 1"	11' 7"	12' 5"	13' 9"	16' 5"	21' 7"	46' 4"	INF	INF
12'	Near	11' 4"	11' 1"	10' 9"	10' 4"	9' 10"	9' 2"	8' 3"	7' 5"	6' 4"	5' 5"	4' 4"
	Far	12' 9"	13' 1"	13' 7"	14' 4"	15' 8"	17' 10"	22' 6"	33' 9"	>100'	INF	INF
15'	Near	14' 0"	13' 8"	13' 2"	12' 6"	11' 8"	10' 9"	9' 7"	8' 5"	7' 1"	5' 11"	4' 8"
	Far	16' 2"	16' 8"	17' 7"	18' 10"	21' 2"	25' 4"	36' 1"	77'	INF	INF	INF
20'	Near	18' 3"	17' 8"	16' 10"	15' 10"	14' 6"	13' 1"	11' 5"	9' 10"	8' 0"	6' 6"	5' 0"
	Far	22' 2"	23' 2"	24' 10"	27' 5"	32' 8"	43' 11"	90'	INF	INF	INF	INF
25'	Near	22' 4"	21' 5"	20' 2"	18' 9"	16' 11"	15' 0"	12' 10"	10' 10"	8' 8"	7' 0"	5' 4"
	Far	28' 5"	30' 1"	33' 0"	37' 10"	48' 7"	78'	>100'	INF	INF	INF	INF
30'	Near	26' 3"	25' 0"	23' 4"	21' 5"	19' 1"	16' 8"	14' 0"	11' 8"	9' 2"	7' 4"	5' 6"
	Far	35' 1"	37' 8"	42' 4"	50'	71'	>100'	INF	INF	INF	INF	INF
50'	Near	40' 4"	37' 5"	33' 9"	29' 11"	25' 6"	21' 4"	17' 2"	13' 10"	10' 5"	8' 1"	5' 11"
	Far	65'	75'	97'	>100'	>100'	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

50mm

Circle of Confusion	Aperture										
1/500in				1.4	2	2.8	4	5.6	8	11	16
1/710in			1.4	2	2.8	4	5.6	8	11	16	22
1/1000in		1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in	1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	323'	231'	161'	115'	81'	58'	40'	29'	20'	15'	10'

Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 11.7	2' 11.6	2' 11.4	2' 11.2	2' 10.8	2' 10.4	2' 9.8"	2' 9.0"	2' 7.8"	2' 6"	2' 5"
	Far	3' 0.3"	3' 0.5"	3' 0.7"	3' 1.0"	3' 1.4"	3' 2.0"	3' 2.9"	3' 4.1"	3' 6.3"	3' 9"	4' 4"
3'6"	Near	3' 5.6"	3' 5.4"	3' 5.2"	3' 4.9"	3' 4.4"	3' 3.8"	3' 2.9"	3' 1.9"	3' 0"	2' 11"	2' 8"
	Far	3' 6.5"	3' 6.6"	3' 6.9"	3' 7.3"	3' 7.9"	3' 8.7"	3' 10.0	3' 11.7	4' 3"	4' 7"	5' 5"
4'	Near	3' 11.5	3' 11.2	3' 10.9	3' 10.5	3' 9.9"	3' 9.1"	3' 8.0"	3' 7"	3' 5"	3' 2"	2' 11"
	Far	4' 0.6"	4' 0.8"	4' 1.2"	4' 1.7"	4' 2.5"	4' 3.6"	4' 5.3"	4' 8"	5' 0"	5' 6"	6' 8"
4'6"	Near	4' 5.3"	4' 5.0"	4' 4.6"	4' 4.1"	4' 3.4"	4' 2.4"	4' 1.0"	3' 11"	3' 9"	3' 6"	3' 2"
	Far	4' 6.8"	4' 7.1"	4' 7.5"	4' 8.2"	4' 9.2"	4' 10.6	5' 0.8"	5' 4"	5' 10"	6' 6"	8' 3"
5'	Near	4' 11.1	4' 10.8	4' 10.3	4' 9.7"	4' 8.7"	4' 7.5"	4' 6"	4' 4"	4' 1"	3' 10"	3' 5"
	Far	5' 0.9"	5' 1.3"	5' 1.9"	5' 2.7"	5' 4.0"	5' 5.7"	5' 9"	6' 0"	6' 8"	7' 8"	10' 1"
5'6"	Near	5' 5.0"	5' 4.6"	5' 4.0"	5' 3.2"	5' 2.0"	5' 1"	4' 11"	4' 8"	4' 5"	4' 1"	3' 8"
	Far	5' 7.1"	5' 7.6"	5' 8.3"	5' 9.3"	5' 10.8	6' 1"	6' 4"	6' 9"	7' 7"	8' 10"	12' 4"
6'	Near	5' 10.8	5' 10.3	5' 9.6"	5' 8.6"	5' 7.3"	5' 6"	5' 3"	5' 0"	4' 8"	4' 4"	3' 10"
	Far	6' 1.4"	6' 1.9"	6' 2.8"	6' 4.0"	6' 5.8"	6' 8"	7' 1"	7' 7"	8' 7"	10' 3"	15' 2"
6'6"	Near	6' 4.5"	6' 4.0"	6' 3.1"	6' 2.0"	6' 0"	5' 10"	5' 8"	5' 5"	5' 0"	4' 7"	4' 1"
	Far	6' 7.6"	6' 8.3"	6' 9.3"	6' 10.7	7' 1"	7' 4"	7' 9"	8' 4"	9' 7"	11' 9"	18' 10"
7'	Near	6' 10.3	6' 9.6"	6' 8.7"	6' 7.4"	6' 6"	6' 3"	6' 0"	5' 9"	5' 3"	4' 10"	4' 3"
	Far	7' 1.9"	7' 2.6"	7' 3.8"	7' 5.4"	7' 8"	8' 0"	8' 6"	9' 2"	10' 9"	13' 6"	23' 9"
8'	Near	7' 9.8"	7' 8.9"	7' 7.7"	7' 6"	7' 4"	7' 1"	6' 9"	6' 4"	5' 10"	5' 3"	4' 7"
	Far	8' 2.4"	8' 3.5"	8' 5.0"	8' 7"	8' 11"	9' 4"	10' 0"	11' 0"	13' 4"	17' 10"	41' 3"
9'	Near	8' 9.2"	8' 8.1"	8' 6.5"	8' 4"	8' 2"	7' 10"	7' 5"	6' 11"	6' 4"	5' 8"	4' 11"
	Far	9' 3.1"	9' 4.4"	9' 6.4"	9' 9"	10' 2"	10' 8"	11' 7"	13' 0"	16' 4"	23' 8"	96'
10'	Near	9' 9"	9' 7"	9' 5"	9' 3"	8' 11"	8' 7"	8' 1"	7' 6"	6' 9"	6' 1"	5' 2"
	Far	10' 4"	10' 5"	10' 8"	10' 11"	11' 5"	12' 1"	13' 4"	15' 3"	20' 0"	32' 2"	INF
12'	Near	11' 7"	11' 5"	11' 2"	10' 11"	10' 6"	10' 0"	9' 4"	8' 7"	7' 8"	6' 9"	5' 7"
	Far	12' 6"	12' 8"	13' 0"	13' 5"	14' 1"	15' 2"	17' 1"	20' 5"	30' 0"	69'	INF
15'	Near	14' 4"	14' 1"	13' 9"	13' 4"	12' 8"	12' 0"	11' 0"	10' 0"	8' 9"	7' 7"	6' 2"
	Far	15' 9"	16' 1"	16' 6"	17' 3"	18' 5"	20' 4"	23' 11"	30' 10"	59'	INF	INF
20'	Near	18' 10"	18' 5"	17' 10"	17' 1"	16' 1"	14' 11"	13' 6"	12' 0"	10' 2"	8' 7"	6' 10"
	Far	21' 4"	21' 11"	22' 10"	24' 2"	26' 7"	30' 8"	39' 10"	63'	>100'	INF	INF
25'	Near	23' 3"	22' 7"	21' 8"	20' 7"	19' 2"	17' 6"	15' 6"	13' 7"	11' 4"	9' 5"	7' 4"
	Far	27' 1"	28' 0"	29' 7"	31' 11"	36' 3"	44' 3"	66'	>100'	INF	INF	INF
30'	Near	27' 6"	26' 7"	25' 4"	23' 10"	21' 11"	19' 10"	17' 4"	15' 0"	12' 2"	10' 0"	7' 8"
	Far	33' 1"	34' 6"	36' 10"	40' 7"	47' 10"	62'	>100'	INF	INF	INF	INF
50'	Near	43' 4"	41' 2"	38' 3"	35' 0"	31' 0"	26' 11"	22' 6"	18' 8"	14' 6"	11' 6"	8' 7"
	Far	59'	63'	72'	88'	>100'	>100'	INF	INF	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

75mm

Circle of Confusion	Aperture										
1/500in				1.4	2	2.8	4	5.6	8	11	16
1/710in			1.4	2	2.8	4	5.6	8	11	16	22
1/1000in		1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in	1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	727'	519'	363'	259'	182'	130'	91'	66'	45'	33'	23'

Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 11.9	2' 11.8	2' 11.7	2' 11.6	2' 11.5	2' 11.3	2' 11.0	2' 10.6	2' 10.0	2' 9.3"	2' 8.2"
	Far	3' 0.1"	3' 0.2"	3' 0.3"	3' 0.4"	3' 0.6"	3' 0.9"	3' 1.2"	3' 1.7"	3' 2.5"	3' 3.6"	3' 5.5"
3'6"	Near	3' 5.8"	3' 5.7"	3' 5.6"	3' 5.5"	3' 5.3"	3' 5.0"	3' 4.6"	3' 4.1"	3' 3.3"	3' 2.3"	3' 1"
	Far	3' 6.2"	3' 6.3"	3' 6.4"	3' 6.6"	3' 6.8"	3' 7.2"	3' 7.7"	3' 8.4"	3' 9.5"	3' 11.0	4' 2"
4'	Near	3' 11.8	3' 11.7	3' 11.5	3' 11.3	3' 11.0	3' 10.7	3' 10.1	3' 9.5"	3' 8.4"	3' 7.2"	3' 5"
	Far	4' 0.3"	4' 0.4"	4' 0.5"	4' 0.8"	4' 1.1"	4' 1.5"	4' 2.2"	4' 3.1"	4' 4.6"	4' 6.6"	4' 10"
4'6"	Near	4' 5.7"	4' 5.6"	4' 5.4"	4' 5.1"	4' 4.8"	4' 4.3"	4' 3.6"	4' 2.8"	4' 1.5"	4' 0"	3' 10"
	Far	4' 6.3"	4' 6.5"	4' 6.7"	4' 7.0"	4' 7.4"	4' 7.9"	4' 8.8"	4' 10.0	4' 12.0	5' 3"	5' 7"
5'	Near	4' 11.6	4' 11.5	4' 11.2	4' 10.9	4' 10.5	4' 9.9"	4' 9.1"	4' 8.0"	4' 6"	4' 5"	4' 2"
	Far	5' 0.4"	5' 0.6"	5' 0.8"	5' 1.2"	5' 1.7"	5' 2.4"	5' 3.5"	5' 4.9"	5' 7"	5' 11"	6' 5"
5'6"	Near	5' 5.5"	5' 5.3"	5' 5.1"	5' 4.7"	5' 4.2"	5' 3.5"	5' 2.5"	5' 1.2"	4' 11"	4' 9"	4' 6"
	Far	5' 6.5"	5' 6.7"	5' 7.0"	5' 7.4"	5' 8.1"	5' 8.9"	5' 10.3	6' 0.0"	6' 3"	6' 7"	7' 3"
6'	Near	5' 11.4	5' 11.2	5' 10.9	5' 10.5	5' 9.8"	5' 9.0"	5' 7.8"	5' 6"	5' 4"	5' 1"	4' 10"
	Far	6' 0.6"	6' 0.8"	6' 1.2"	6' 1.7"	6' 2.5"	6' 3.5"	6' 5.1"	6' 7"	6' 11"	7' 4"	8' 2"
6'6"	Near	6' 5.3"	6' 5.1"	6' 4.7"	6' 4.2"	6' 3.4"	6' 2.5"	6' 1.0"	5' 11"	5' 9"	5' 6"	5' 1"
	Far	6' 6.7"	6' 7.0"	6' 7.4"	6' 8.0"	6' 8.9"	6' 10.1	7' 0.0"	7' 3"	7' 7"	8' 1"	9' 2"
7'	Near	6' 11.2	6' 10.9	6' 10.5	6' 9.9"	6' 9.0"	6' 7.9"	6' 6"	6' 4"	6' 1"	5' 10"	5' 5"
	Far	7' 0.8"	7' 1.1"	7' 1.7"	7' 2.3"	7' 3.4"	7' 4.8"	7' 7"	7' 10"	8' 3"	8' 11"	10' 2"
8'	Near	7' 11.0	7' 10.6	7' 10.0	7' 9.2"	7' 8.1"	7' 6.6"	7' 5"	7' 2"	6' 10"	6' 6"	6' 0"
	Far	8' 1.1"	8' 1.5"	8' 2.2"	8' 3.1"	8' 4.4"	8' 6.3"	8' 9"	9' 1"	9' 9"	10' 7"	12' 5"
9'	Near	8' 10.7	8' 10.2	8' 9.5"	8' 8.5"	8' 7.1"	8' 5"	8' 3"	7' 11"	7' 7"	7' 2"	6' 6"
	Far	9' 1.4"	9' 1.9"	9' 2.7"	9' 3.9"	9' 5.6"	9' 8"	10' 0"	10' 5"	11' 3"	12' 5"	15' 0"
10'	Near	9' 10"	9' 10"	9' 9"	9' 8"	9' 6"	9' 4"	9' 0"	8' 9"	8' 3"	7' 9"	7' 0"
	Far	10' 2"	10' 2"	10' 3"	10' 5"	10' 7"	10' 10"	11' 3"	11' 9"	12' 10"	14' 4"	18' 0"
12'	Near	11' 10"	11' 9"	11' 8"	11' 6"	11' 3"	11' 0"	10' 8"	10' 2"	9' 7"	8' 11"	7' 11"
	Far	12' 2"	12' 3"	12' 5"	12' 7"	12' 10"	13' 3"	13' 10"	14' 8"	16' 4"	18' 11"	25' 8"
15'	Near	14' 8"	14' 7"	14' 5"	14' 2"	13' 11"	13' 6"	12' 11"	12' 3"	11' 4"	10' 5"	9' 2"
	Far	15' 4"	15' 5"	15' 8"	15' 11"	16' 4"	17' 0"	18' 0"	19' 5"	22' 5"	27' 7"	44' 10"
20'	Near	19' 6"	19' 3"	19' 0"	18' 7"	18' 1"	17' 4"	16' 5"	15' 5"	14' 0"	12' 7"	10' 9"
	Far	20' 7"	20' 10"	21' 2"	21' 8"	22' 6"	23' 8"	25' 8"	28' 9"	35' 10"	51'	>100'
25'	Near	24' 2"	23' 10"	23' 5"	22' 10"	22' 0"	21' 0"	19' 8"	18' 3"	16' 3"	14' 4"	12' 0"
	Far	25' 11"	26' 3"	26' 10"	27' 8"	29' 0"	31' 0"	34' 6"	40' 3"	55'	>100'	INF
30'	Near	28' 10"	28' 5"	27' 9"	26' 11"	25' 9"	24' 5"	22' 7"	20' 9"	18' 2"	15' 10"	13' 1"
	Far	31' 4"	31' 10"	32' 8"	33' 11"	35' 11"	39' 0"	44' 10"	55'	89'	>100'	INF
50'	Near	46' 10"	45' 8"	44' 0"	42' 0"	39' 3"	36' 2"	32' 4"	28' 7"	23' 11"	20' 0"	15' 9"
	Far	53'	55'	57'	61'	69'	81'	>100'	>100'	INF	INF	INF

DEPTH OF FIELD
Feet and Inches

100mm

Circle of Confusion		Aperture										
1/500in					1.4	2	2.8	4	5.6	8	11	16
1/710in				1.4	2	2.8	4	5.6	8	11	16	22
1/1000in			1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in		1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		1292'	923'	646'	461'	323'	231'	161'	117'	81'	59'	40'
Focus distance		Extreme distance in acceptable focus										
3'	Near	2' 11.9	2' 11.9	2' 11.9	2' 11.8	2' 11.7	2' 11.6	2' 11.4	2' 11.2	2' 10.8	2' 10.4	2' 9.8"
	Far	3' 0.1"	3' 0.1"	3' 0.2"	3' 0.2"	3' 0.3"	3' 0.5"	3' 0.7"	3' 0.9"	3' 1.4"	3' 1.9"	3' 2.9"
3'6"	Near	3' 5.9"	3' 5.9"	3' 5.8"	3' 5.7"	3' 5.6"	3' 5.4"	3' 5.2"	3' 4.9"	3' 4.4"	3' 3.9"	3' 2.9"
	Far	3' 6.1"	3' 6.2"	3' 6.2"	3' 6.3"	3' 6.5"	3' 6.6"	3' 6.9"	3' 7.3"	3' 7.9"	3' 8.7"	3' 10.0
4'	Near	3' 11.9	3' 11.8	3' 11.7	3' 11.6	3' 11.5	3' 11.2	3' 10.9	3' 10.5	3' 9.9"	3' 9.2"	3' 8.0"
	Far	4' 0.1"	4' 0.2"	4' 0.3"	4' 0.4"	4' 0.6"	4' 0.8"	4' 1.2"	4' 1.7"	4' 2.5"	4' 3.5"	4' 5.3"
4'6"	Near	4' 5.8"	4' 5.8"	4' 5.7"	4' 5.5"	4' 5.3"	4' 5.0"	4' 4.6"	4' 4.1"	4' 3.4"	4' 2.4"	4' 1.0"
	Far	4' 6.2"	4' 6.3"	4' 6.4"	4' 6.5"	4' 6.8"	4' 7.1"	4' 7.5"	4' 8.2"	4' 9.2"	4' 10.5	5' 0.8"
5'	Near	4' 11.8	4' 11.7	4' 11.6	4' 11.4	4' 11.1	4' 10.8	4' 10.3	4' 9.7"	4' 8.7"	4' 7.6"	4' 6"
	Far	5' 0.2"	5' 0.3"	5' 0.5"	5' 0.7"	5' 0.9"	5' 1.3"	5' 1.9"	5' 2.7"	5' 4.0"	5' 5.6"	5' 9"
5'6"	Near	5' 5.7"	5' 5.6"	5' 5.5"	5' 5.3"	5' 5.0"	5' 4.6"	5' 4.0"	5' 3.2"	5' 2.0"	5' 1"	4' 11"
	Far	5' 6.3"	5' 6.4"	5' 6.6"	5' 6.8"	5' 7.1"	5' 7.6"	5' 8.3"	5' 9.2"	5' 10.8	6' 1"	6' 4"
6'	Near	5' 11.7	5' 11.6	5' 11.4	5' 11.1	5' 10.8	5' 10.3	5' 9.6"	5' 8.7"	5' 7.3"	5' 6"	5' 3"
	Far	6' 0.3"	6' 0.5"	6' 0.7"	6' 0.9"	6' 1.4"	6' 1.9"	6' 2.8"	6' 3.9"	6' 5.8"	6' 8"	7' 1"
6'6"	Near	6' 5.6"	6' 5.5"	6' 5.3"	6' 5.0"	6' 4.5"	6' 4.0"	6' 3.1"	6' 2.1"	6' 0"	5' 11"	5' 8"
	Far	6' 6.4"	6' 6.6"	6' 6.8"	6' 7.1"	6' 7.6"	6' 8.3"	6' 9.3"	6' 10.6	7' 1"	7' 4"	7' 9"
7'	Near	6' 11.6	6' 11.4	6' 11.1	6' 10.8	6' 10.3	6' 9.6"	6' 8.7"	6' 7.5"	6' 6"	6' 3"	6' 0"
	Far	7' 0.5"	7' 0.6"	7' 0.9"	7' 1.3"	7' 1.9"	7' 2.6"	7' 3.8"	7' 5.3"	7' 8"	7' 11"	8' 6"
8'	Near	7' 11.4	7' 11.2	7' 10.9	7' 10.4	7' 9.8"	7' 8.9"	7' 7.7"	7' 6"	7' 4"	7' 1"	6' 9"
	Far	8' 0.6"	8' 0.8"	8' 1.2"	8' 1.7"	8' 2.4"	8' 3.5"	8' 5.0"	8' 7"	8' 11"	9' 3"	10' 0"
9'	Near	8' 11.3	8' 11.0	8' 10.6	8' 10.0	8' 9.2"	8' 8.1"	8' 6.5"	8' 5"	8' 2"	7' 10"	7' 5"
	Far	9' 0.8"	9' 1.1"	9' 1.5"	9' 2.1"	9' 3.1"	9' 4.4"	9' 6.4"	9' 9"	10' 2"	10' 8"	11' 7"
10'	Near	9' 11"	9' 11"	9' 10"	9' 10"	9' 9"	9' 7"	9' 5"	9' 3"	8' 11"	8' 7"	8' 1"
	Far	10' 1"	10' 1"	10' 2"	10' 3"	10' 4"	10' 5"	10' 8"	10' 11"	11' 5"	12' 1"	13' 4"
12'	Near	11' 11"	11' 10"	11' 9"	11' 8"	11' 7"	11' 5"	11' 2"	10' 11"	10' 6"	10' 0"	9' 4"
	Far	12' 1"	12' 2"	12' 3"	12' 4"	12' 6"	12' 8"	13' 0"	13' 4"	14' 1"	15' 1"	17' 1"
15'	Near	14' 10"	14' 9"	14' 8"	14' 6"	14' 4"	14' 1"	13' 9"	13' 4"	12' 8"	12' 0"	11' 0"
	Far	15' 2"	15' 3"	15' 4"	15' 6"	15' 9"	16' 1"	16' 6"	17' 2"	18' 5"	20' 2"	23' 11"
20'	Near	19' 8"	19' 7"	19' 5"	19' 2"	18' 10"	18' 5"	17' 10"	17' 2"	16' 1"	15' 0"	13' 6"
	Far	20' 4"	20' 5"	20' 8"	20' 11"	21' 4"	21' 11"	22' 10"	24' 1"	26' 7"	30' 5"	39' 10"
25'	Near	24' 6"	24' 4"	24' 1"	23' 9"	23' 3"	22' 7"	21' 8"	20' 8"	19' 2"	17' 7"	15' 6"
	Far	25' 6"	25' 8"	26' 0"	26' 5"	27' 1"	28' 0"	29' 7"	31' 9"	36' 3"	43' 8"	66'
30'	Near	29' 4"	29' 1"	28' 8"	28' 2"	27' 6"	26' 7"	25' 4"	23' 11"	21' 11"	19' 11"	17' 4"
	Far	30' 9"	31' 0"	31' 6"	32' 1"	33' 1"	34' 6"	36' 10"	40' 4"	47' 10"	61'	>100'
50'	Near	48' 2"	47' 5"	46' 5"	45' 2"	43' 4"	41' 2"	38' 3"	35' 2"	31' 0"	27' 1"	22' 6"
	Far	52'	52'	54'	56'	59'	63'	72'	87'	>100'	>100'	INF

DEPTH OF FIELD
Feet and Inches

150mm

Circle of Confusion	Aperture										
1/500in				1.4	2	2.8	4	5.6	8	11	16
1/710in			1.4	2	2.8	4	5.6	8	11	16	22
1/1000in		1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in	1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in	2	2.8	4	5.6	8	11	16	22	32		

Hyperfocal dist'	2906'	2076'	1453'	1038'	727'	519'	363'	264'	182'	132'	91'

Focus distance		Extreme distance in acceptable focus										
3'	Near	3' 0.0"	3' 0.0"	2' 11.9	2' 11.9	2' 11.9	2' 11.8	2' 11.7	2' 11.6	2' 11.5	2' 11.3	2' 11.0
	Far	3' 0.0"	3' 0.1"	3' 0.1"	3' 0.1"	3' 0.1"	3' 0.2"	3' 0.3"	3' 0.4"	3' 0.6"	3' 0.8"	3' 1.2"
3'6"	Near	3' 6.0"	3' 5.9"	3' 5.9"	3' 5.9"	3' 5.8"	3' 5.7"	3' 5.6"	3' 5.5"	3' 5.3"	3' 5.0"	3' 4.6"
	Far	3' 6.1"	3' 6.1"	3' 6.1"	3' 6.1"	3' 6.2"	3' 6.3"	3' 6.4"	3' 6.6"	3' 6.8"	3' 7.1"	3' 7.7"
4'	Near	3' 11.9	3' 11.9	3' 11.9	3' 11.8	3' 11.8	3' 11.7	3' 11.5	3' 11.3	3' 11.0	3' 10.7	3' 10.1
	Far	4' 0.1"	4' 0.1"	4' 0.1"	4' 0.2"	4' 0.3"	4' 0.4"	4' 0.5"	4' 0.7"	4' 1.1"	4' 1.5"	4' 2.2"
4'6"	Near	4' 5.9"	4' 5.9"	4' 5.8"	4' 5.8"	4' 5.7"	4' 5.6"	4' 5.4"	4' 5.2"	4' 4.8"	4' 4.3"	4' 3.6"
	Far	4' 6.1"	4' 6.1"	4' 6.2"	4' 6.2"	4' 6.3"	4' 6.5"	4' 6.7"	4' 6.9"	4' 7.4"	4' 7.9"	4' 8.8"
5'	Near	4' 11.9	4' 11.9	4' 11.8	4' 11.7	4' 11.6	4' 11.5	4' 11.2	4' 11.0	4' 10.5	4' 10.0	4' 9.1"
	Far	5' 0.1"	5' 0.1"	5' 0.2"	5' 0.3"	5' 0.4"	5' 0.6"	5' 0.8"	5' 1.2"	5' 1.7"	5' 2.4"	5' 3.5"
5'6"	Near	5' 5.9"	5' 5.8"	5' 5.8"	5' 5.7"	5' 5.5"	5' 5.3"	5' 5.1"	5' 4.7"	5' 4.2"	5' 3.5"	5' 2.5"
	Far	5' 6.1"	5' 6.2"	5' 6.3"	5' 6.4"	5' 6.5"	5' 6.7"	5' 7.0"	5' 7.4"	5' 8.1"	5' 8.9"	5' 10.3
6'	Near	5' 11.9	5' 11.8	5' 11.7	5' 11.6	5' 11.4	5' 11.2	5' 10.9	5' 10.5	5' 9.8"	5' 9.0"	5' 7.8"
	Far	6' 0.1"	6' 0.2"	6' 0.3"	6' 0.4"	6' 0.6"	6' 0.8"	6' 1.2"	6' 1.7"	6' 2.5"	6' 3.4"	6' 5.1"
6'6"	Near	6' 5.8"	6' 5.8"	6' 5.7"	6' 5.5"	6' 5.3"	6' 5.1"	6' 4.7"	6' 4.2"	6' 3.4"	6' 2.5"	6' 1.0"
	Far	6' 6.2"	6' 6.2"	6' 6.4"	6' 6.5"	6' 6.7"	6' 7.0"	6' 7.4"	6' 8.0"	6' 8.9"	6' 10.0	7' 0.0"
7'	Near	6' 11.8	6' 11.7	6' 11.6	6' 11.5	6' 11.2	6' 10.9	6' 10.5	6' 9.9"	6' 9.0"	6' 8.0"	6' 6"
	Far	7' 0.2"	7' 0.3"	7' 0.4"	7' 0.6"	7' 0.8"	7' 1.1"	7' 1.7"	7' 2.3"	7' 3.4"	7' 4.7"	7' 7"
8'	Near	7' 11.7	7' 11.6	7' 11.5	7' 11.3	7' 11.0	7' 10.6	7' 10.0	7' 9.3"	7' 8.1"	7' 6.7"	7' 5"
	Far	8' 0.3"	8' 0.4"	8' 0.5"	8' 0.7"	8' 1.1"	8' 1.5"	8' 2.2"	8' 3.0"	8' 4.4"	8' 6.2"	8' 9"
9'	Near	8' 11.7	8' 11.6	8' 11.4	8' 11.1	8' 10.7	8' 10.2	8' 9.5"	8' 8.6"	8' 7.1"	8' 5"	8' 3"
	Far	9' 0.3"	9' 0.5"	9' 0.7"	9' 0.9"	9' 1.4"	9' 1.9"	9' 2.7"	9' 3.8"	9' 5.6"	9' 8"	10' 0"
10'	Near	10' 0"	9' 11"	9' 11"	9' 11"	9' 10"	9' 10"	9' 9"	9' 8"	9' 6"	9' 4"	9' 0"
	Far	10' 0"	10' 1"	10' 1"	10' 1"	10' 2"	10' 2"	10' 3"	10' 5"	10' 7"	10' 10"	11' 3"
12'	Near	11' 11"	11' 11"	11' 11"	11' 10"	11' 10"	11' 9"	11' 8"	11' 6"	11' 3"	11' 0"	10' 8"
	Far	12' 1"	12' 1"	12' 1"	12' 2"	12' 2"	12' 3"	12' 5"	12' 7"	12' 10"	13' 2"	13' 10"
15'	Near	14' 11"	14' 11"	14' 10"	14' 9"	14' 8"	14' 7"	14' 5"	14' 3"	13' 11"	13' 6"	12' 11"
	Far	15' 1"	15' 1"	15' 2"	15' 3"	15' 4"	15' 5"	15' 8"	15' 11"	16' 4"	16' 11"	18' 0"
20'	Near	19' 10"	19' 10"	19' 9"	19' 8"	19' 6"	19' 3"	19' 0"	18' 7"	18' 1"	17' 5"	16' 5"
	Far	20' 2"	20' 2"	20' 3"	20' 5"	20' 7"	20' 10"	21' 2"	21' 8"	22' 6"	23' 7"	25' 8"
25'	Near	24' 9"	24' 8"	24' 7"	24' 5"	24' 2"	23' 10"	23' 5"	22' 10"	22' 0"	21' 1"	19' 8"
	Far	25' 3"	25' 4"	25' 5"	25' 7"	25' 11"	26' 3"	26' 10"	27' 7"	29' 0"	30' 10"	34' 6"
30'	Near	29' 8"	29' 7"	29' 5"	29' 2"	28' 10"	28' 5"	27' 9"	27' 0"	25' 9"	24' 6"	22' 7"
	Far	30' 4"	30' 5"	30' 8"	30' 11"	31' 4"	31' 10"	32' 8"	33' 10"	35' 11"	38' 10"	44' 10"
50'	Near	49' 2"	48' 10"	48' 4"	47' 9"	46' 10"	45' 8"	44' 0"	42' 1"	39' 3"	36' 4"	32' 4"
	Far	50'	51'	51'	52'	53'	55'	57'	61'	69'	80'	>100'

DEPTH OF FIELD
Feet and Inches

200mm

Circle of Confusion		Aperture										
1/500in					1.4	2	2.8	4	5.6	8	11	16
1/710in				1.4	2	2.8	4	5.6	8	11	16	22
1/1000in			1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in		1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		5167'	3690'	2583'	1845'	1292'	923'	646'	470'	323'	235'	161'
Focus distance		Extreme distance in acceptable focus										
3'	Near	3' 0.0"	3' 0.0"	3' 0.0"	2' 11.9	2' 11.9	2' 11.9	2' 11.9	2' 11.8	2' 11.7	2' 11.6	2' 11.4
	Far	3' 0.0"	3' 0.0"	3' 0.0"	3' 0.1"	3' 0.1"	3' 0.1"	3' 0.2"	3' 0.2"	3' 0.3"	3' 0.5"	3' 0.7"
3'6"	Near	3' 6.0"	3' 6.0"	3' 5.9"	3' 5.9"	3' 5.9"	3' 5.9"	3' 5.8"	3' 5.7"	3' 5.6"	3' 5.4"	3' 5.2"
	Far	3' 6.0"	3' 6.0"	3' 6.1"	3' 6.1"	3' 6.1"	3' 6.2"	3' 6.2"	3' 6.3"	3' 6.5"	3' 6.6"	3' 6.9"
4'	Near	4' 0.0"	4' 0.0"	3' 11.9	3' 11.9	3' 11.9	3' 11.8	3' 11.7	3' 11.6	3' 11.5	3' 11.3	3' 10.9
	Far	4' 0.0"	4' 0.1"	4' 0.1"	4' 0.1"	4' 0.1"	4' 0.2"	4' 0.3"	4' 0.4"	4' 0.6"	4' 0.8"	4' 1.2"
4'6"	Near	4' 6.0"	4' 5.9"	4' 5.9"	4' 5.9"	4' 5.8"	4' 5.8"	4' 5.7"	4' 5.5"	4' 5.3"	4' 5.1"	4' 4.6"
	Far	4' 6.0"	4' 6.1"	4' 6.1"	4' 6.1"	4' 6.2"	4' 6.3"	4' 6.4"	4' 6.5"	4' 6.8"	4' 7.1"	4' 7.5"
5'	Near	4' 11.9	4' 11.9	4' 11.9	4' 11.8	4' 11.8	4' 11.7	4' 11.6	4' 11.4	4' 11.1	4' 10.8	4' 10.3
	Far	5' 0.1"	5' 0.1"	5' 0.1"	5' 0.2"	5' 0.2"	5' 0.3"	5' 0.5"	5' 0.6"	5' 0.9"	5' 1.3"	5' 1.9"
5'6"	Near	5' 5.9"	5' 5.9"	5' 5.9"	5' 5.8"	5' 5.7"	5' 5.6"	5' 5.5"	5' 5.3"	5' 5.0"	5' 4.6"	5' 4.0"
	Far	5' 6.1"	5' 6.1"	5' 6.1"	5' 6.2"	5' 6.3"	5' 6.4"	5' 6.6"	5' 6.8"	5' 7.1"	5' 7.6"	5' 8.3"
6'	Near	5' 11.9	5' 11.9	5' 11.8	5' 11.8	5' 11.7	5' 11.6	5' 11.4	5' 11.1	5' 10.8	5' 10.3	5' 9.6"
	Far	6' 0.1"	6' 0.1"	6' 0.2"	6' 0.2"	6' 0.3"	6' 0.5"	6' 0.7"	6' 0.9"	6' 1.4"	6' 1.9"	6' 2.8"
6'6"	Near	6' 5.9"	6' 5.9"	6' 5.8"	6' 5.7"	6' 5.6"	6' 5.5"	6' 5.3"	6' 5.0"	6' 4.5"	6' 4.0"	6' 3.1"
	Far	6' 6.1"	6' 6.1"	6' 6.2"	6' 6.3"	6' 6.4"	6' 6.6"	6' 6.8"	6' 7.1"	6' 7.6"	6' 8.2"	6' 9.3"
7'	Near	6' 11.9	6' 11.8	6' 11.8	6' 11.7	6' 11.6	6' 11.4	6' 11.1	6' 10.8	6' 10.3	6' 9.7"	6' 8.7"
	Far	7' 0.1"	7' 0.2"	7' 0.2"	7' 0.3"	7' 0.5"	7' 0.6"	7' 0.9"	7' 1.3"	7' 1.9"	7' 2.6"	7' 3.8"
8'	Near	7' 11.9	7' 11.8	7' 11.7	7' 11.6	7' 11.4	7' 11.2	7' 10.9	7' 10.5	7' 9.8"	7' 9.0"	7' 7.7"
	Far	8' 0.1"	8' 0.2"	8' 0.3"	8' 0.4"	8' 0.6"	8' 0.8"	8' 1.2"	8' 1.7"	8' 2.4"	8' 3.4"	8' 5.0"
9'	Near	8' 11.8	8' 11.7	8' 11.6	8' 11.5	8' 11.3	8' 11.0	8' 10.6	8' 10.0	8' 9.2"	8' 8.2"	8' 6.5"
	Far	9' 0.2"	9' 0.3"	9' 0.4"	9' 0.5"	9' 0.8"	9' 1.1"	9' 1.5"	9' 2.1"	9' 3.1"	9' 4.3"	9' 6.4"
10'	Near	10' 0"	10' 0"	10' 0"	9' 11"	9' 11"	9' 11"	9' 10"	9' 10"	9' 9"	9' 7"	9' 5"
	Far	10' 0"	10' 0"	10' 0"	10' 1"	10' 1"	10' 1"	10' 2"	10' 3"	10' 4"	10' 5"	10' 8"
12'	Near	12' 0"	12' 0"	11' 11"	11' 11"	11' 11"	11' 10"	11' 9"	11' 9"	11' 7"	11' 5"	11' 2"
	Far	12' 0"	12' 0"	12' 1"	12' 1"	12' 1"	12' 2"	12' 3"	12' 4"	12' 6"	12' 8"	13' 0"
15'	Near	14' 11"	14' 11"	14' 11"	14' 11"	14' 10"	14' 9"	14' 8"	14' 7"	14' 4"	14' 1"	13' 9"
	Far	15' 1"	15' 1"	15' 1"	15' 1"	15' 2"	15' 3"	15' 4"	15' 6"	15' 9"	16' 0"	16' 6"
20'	Near	19' 11"	19' 11"	19' 10"	19' 9"	19' 8"	19' 7"	19' 5"	19' 2"	18' 10"	18' 5"	17' 10"
	Far	20' 1"	20' 1"	20' 2"	20' 3"	20' 4"	20' 5"	20' 8"	20' 11"	21' 4"	21' 10"	22' 10"
25'	Near	24' 11"	24' 10"	24' 9"	24' 8"	24' 6"	24' 4"	24' 1"	23' 9"	23' 3"	22' 8"	21' 8"
	Far	25' 1"	25' 2"	25' 3"	25' 4"	25' 6"	25' 8"	26' 0"	26' 5"	27' 1"	28' 0"	29' 7"
30'	Near	29' 10"	29' 9"	29' 8"	29' 6"	29' 4"	29' 1"	28' 8"	28' 3"	27' 6"	26' 8"	25' 4"
	Far	30' 2"	30' 3"	30' 4"	30' 6"	30' 9"	31' 0"	31' 6"	32' 1"	33' 1"	34' 5"	36' 10"
50'	Near	49' 6"	49' 4"	49' 1"	48' 8"	48' 2"	47' 5"	46' 5"	45' 3"	43' 4"	41' 3"	38' 3"
	Far	50'	50'	50'	51'	52'	52'	54'	55'	59'	63'	72'

DEPTH OF FIELD
Feet and Inches

250mm

Circle of Confusion		Aperture										
1/500in					1.4	2	2.8	4	5.6	8	11	16
1/710in				1.4	2	2.8	4	5.6	8	11	16	22
1/1000in			1.4	2	2.8	4	5.6	8	11	16	22	32
1/1420in		1.4	2	2.8	4	5.6	8	11	16	22	32	
1/2000in		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		8073'	5766'	4036'	2883'	2018'	1442'	1009'	734'	505'	367'	252'
Focus distance		Extreme distance in acceptable focus										
3'	Near	3' 0.0"	3' 0.0"	3' 0.0"	3' 0.0"	3' 0.0"	2' 11.9	2' 11.9	2' 11.9	2' 11.8	2' 11.7	2' 11.6
	Far	3' 0.0"	3' 0.0"	3' 0.0"	3' 0.0"	3' 0.1"	3' 0.1"	3' 0.1"	3' 0.1"	3' 0.2"	3' 0.3"	3' 0.4"
3'6"	Near	3' 6.0"	3' 6.0"	3' 6.0"	3' 6.0"	3' 5.9"	3' 5.9"	3' 5.9"	3' 5.8"	3' 5.7"	3' 5.6"	3' 5.5"
	Far	3' 6.0"	3' 6.0"	3' 6.0"	3' 6.1"	3' 6.1"	3' 6.1"	3' 6.1"	3' 6.2"	3' 6.3"	3' 6.4"	3' 6.6"
4'	Near	4' 0.0"	4' 0.0"	4' 0.0"	3' 11.9	3' 11.9	3' 11.9	3' 11.8	3' 11.8	3' 11.7	3' 11.5	3' 11.3
	Far	4' 0.0"	4' 0.0"	4' 0.0"	4' 0.1"	4' 0.1"	4' 0.1"	4' 0.2"	4' 0.3"	4' 0.4"	4' 0.5"	4' 0.8"
4'6"	Near	4' 6.0"	4' 6.0"	4' 5.9"	4' 5.9"	4' 5.9"	4' 5.8"	4' 5.8"	4' 5.7"	4' 5.6"	4' 5.4"	4' 5.1"
	Far	4' 6.0"	4' 6.0"	4' 6.1"	4' 6.1"	4' 6.1"	4' 6.2"	4' 6.2"	4' 6.3"	4' 6.5"	4' 6.7"	4' 7.0"
5'	Near	5' 0.0"	5' 0.0"	4' 11.9	4' 11.9	4' 11.9	4' 11.8	4' 11.7	4' 11.6	4' 11.4	4' 11.2	4' 10.9
	Far	5' 0.0"	5' 0.1"	5' 0.1"	5' 0.1"	5' 0.1"	5' 0.2"	5' 0.3"	5' 0.4"	5' 0.6"	5' 0.8"	5' 1.2"
5'6"	Near	5' 6.0"	5' 5.9"	5' 5.9"	5' 5.9"	5' 5.8"	5' 5.8"	5' 5.7"	5' 5.5"	5' 5.3"	5' 5.1"	5' 4.7"
	Far	5' 6.0"	5' 6.1"	5' 6.1"	5' 6.1"	5' 6.2"	5' 6.3"	5' 6.4"	5' 6.5"	5' 6.7"	5' 7.0"	5' 7.5"
6'	Near	5' 11.9	5' 11.9	5' 11.9	5' 11.9	5' 11.8	5' 11.7	5' 11.6	5' 11.4	5' 11.2	5' 10.9	5' 10.4
	Far	6' 0.1"	6' 0.1"	6' 0.1"	6' 0.2"	6' 0.2"	6' 0.3"	6' 0.4"	6' 0.6"	6' 0.9"	6' 1.2"	6' 1.8"
6'6"	Near	6' 5.9"	6' 5.9"	6' 5.9"	6' 5.8"	6' 5.8"	6' 5.7"	6' 5.5"	6' 5.3"	6' 5.1"	6' 4.7"	6' 4.1"
	Far	6' 6.1"	6' 6.1"	6' 6.1"	6' 6.2"	6' 6.3"	6' 6.4"	6' 6.5"	6' 6.7"	6' 7.0"	6' 7.4"	6' 8.1"
7'	Near	6' 11.9	6' 11.9	6' 11.9	6' 11.8	6' 11.7	6' 11.6	6' 11.4	6' 11.2	6' 10.9	6' 10.5	6' 9.8"
	Far	7' 0.1"	7' 0.1"	7' 0.1"	7' 0.2"	7' 0.3"	7' 0.4"	7' 0.6"	7' 0.8"	7' 1.2"	7' 1.6"	7' 2.4"
8'	Near	7' 11.9	7' 11.9	7' 11.8	7' 11.7	7' 11.6	7' 11.5	7' 11.3	7' 11.0	7' 10.6	7' 10.0	7' 9.2"
	Far	8' 0.1"	8' 0.1"	8' 0.2"	8' 0.3"	8' 0.4"	8' 0.5"	8' 0.8"	8' 1.1"	8' 1.5"	8' 2.1"	8' 3.1"
9'	Near	8' 11.9	8' 11.8	8' 11.8	8' 11.7	8' 11.5	8' 11.4	8' 11.1	8' 10.7	8' 10.2	8' 9.5"	8' 8.4"
	Far	9' 0.1"	9' 0.2"	9' 0.2"	9' 0.3"	9' 0.5"	9' 0.7"	9' 1.0"	9' 1.3"	9' 2.0"	9' 2.7"	9' 4.0"
10'	Near	10' 0"	10' 0"	10' 0"	10' 0"	9' 11"	9' 11"	9' 11"	9' 10"	9' 10"	9' 9"	9' 8"
	Far	10' 0"	10' 0"	10' 0"	10' 0"	10' 1"	10' 1"	10' 1"	10' 2"	10' 2"	10' 3"	10' 5"
12'	Near	12' 0"	12' 0"	12' 0"	11' 11"	11' 11"	11' 11"	11' 10"	11' 10"	11' 9"	11' 8"	11' 6"
	Far	12' 0"	12' 0"	12' 0"	12' 1"	12' 1"	12' 1"	12' 2"	12' 2"	12' 4"	12' 5"	12' 7"
15'	Near	15' 0"	15' 0"	14' 11"	14' 11"	14' 11"	14' 10"	14' 9"	14' 8"	14' 7"	14' 5"	14' 2"
	Far	15' 0"	15' 0"	15' 1"	15' 1"	15' 1"	15' 2"	15' 3"	15' 4"	15' 6"	15' 8"	15' 11"
20'	Near	19' 11"	19' 11"	19' 11"	19' 10"	19' 10"	19' 9"	19' 7"	19' 6"	19' 3"	19' 0"	18' 7"
	Far	20' 1"	20' 1"	20' 1"	20' 2"	20' 2"	20' 3"	20' 5"	20' 7"	20' 10"	21' 2"	21' 9"
25'	Near	24' 11"	24' 11"	24' 10"	24' 9"	24' 8"	24' 7"	24' 5"	24' 2"	23' 10"	23' 5"	22' 9"
	Far	25' 1"	25' 1"	25' 2"	25' 3"	25' 4"	25' 5"	25' 8"	25' 11"	26' 4"	26' 10"	27' 9"
30'	Near	29' 11"	29' 10"	29' 9"	29' 8"	29' 7"	29' 5"	29' 2"	28' 10"	28' 4"	27' 9"	26' 10"
	Far	30' 1"	30' 2"	30' 3"	30' 4"	30' 5"	30' 8"	30' 11"	31' 3"	31' 11"	32' 8"	34' 1"
50'	Near	49' 8"	49' 7"	49' 5"	49' 2"	48' 10"	48' 4"	47' 8"	46' 10"	45' 6"	44' 0"	41' 9"
	Far	50'	50'	50'	50'	51'	51'	52'	53'	55'	57'	62'

13.10 DEPTH OF FIELD TABLES, METRIC

The following Depth of Field tables list near and far distances in acceptable focus covering a range of four circles of confusion, 13 lens focal lengths, 19 intermediate point of focus distances and two numeric systems and are as many as can be conveniently accommodated in a manual such as this. The increments are close enough to permit the user to interpolate focal lengths and distances to suit actual conditions.

As already discussed, many factors influence depth of field calculations and all lenses are different depending upon their design and constgruction. For all of these reasons calculated depth of field tables can only be approximations. See Section 13.8.

In the final analysis, what is and what is not in acceptable focus is a subjective decision which can be made only after viewing results on the screen and will depend upon many variables. Only when results have been seen, and compared to what the tables forecast, can a suitable circle of confusion on which to make future predictions be determined.

Having seen results or tests and decided which is the near and far distances in acceptable focus for a given lens at a given distance and at a known aperture the circle of confusion can be determined by tracing these conditions backwards on the following tables and noting the circle of confusion which best gave those results for that combination of circumstances. This setting may then be used to calculate similar results in the future.

If the suitable circle of confusion is known note the top left hand column (0.05 - 0.012mm) and use an aperture setting along that line.

If starting out without making prior tests a circle of confusion of 0.025 or 0.017mm is likely to be most suitable for most shooting using modern lenses on modern filmstocks and without any diffusion.

To select a 'biased' Depth of Field setting, where, say, near subjects are always more in-focus than far subjects, select a smaller circle of confusion for the near distance and a proportionately larger c of c for the far distance. The same method can be used to cope with lenses which have an inherent optical bias one way or another.

These Depth of Field tables have been generated on a computer spreadsheet program using the formula described in Section 15.6.3 as follows:

Focal length lens calculations are based on a Fixed Nodal Constant of 50mm.

Where the total depth of field is less than 1 meter distances are rounded off to 1 mm.

Distances greater than 50 meters are rounded off to the nearest 1 m.

DEPTH OF FIELD
Metric

10mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	4m	3m	2m	1.4m	1m	0.7m	0.5m	0.4m	0.3m	0.2m	0.1m
Focus distance	Extreme distance in acceptable focus, meters										
1 m Near	0.82	0.76	0.69	0.62	0.5	0.5	0.4	0.3	0.2	0.2	0.2
Far	1.3	1.5	1.9	2.9	19.1	INF	INF	INF	INF	INF	INF
1.2 m Near	0.94	0.87	0.78	0.7	0.6	0.5	0.4	0.3	0.3	0.2	0.2
Far	1.7	2	2.8	5.9	INF	INF	INF	INF	INF	INF	INF
1.4 m Near	1.06	0.97	0.86	0.7	0.6	0.5	0.4	0.3	0.3	0.2	0.2
Far	2.1	2.6	4.2	24.5	INF	INF	INF	INF	INF	INF	INF
1.6 m Near	1.17	1.05	0.9	0.8	0.7	0.5	0.4	0.3	0.3	0.2	0.2
Far	2.6	3.4	6.9	INF	INF	INF	INF	INF	INF	INF	INF
1.8 m Near	1.27	1.14	1	0.8	0.7	0.6	0.4	0.4	0.3	0.2	0.2
Far	3.2	4.6	14.1	INF	INF	INF	INF	INF	INF	INF	INF
2 m Near	1.36	1.21	1	0.9	0.7	0.6	0.4	0.4	0.3	0.2	0.2
Far	3.9	6.2	78.1	INF	INF	INF	INF	INF	INF	INF	INF
2.25 m Near	1.47	1.3	1.1	0.9	0.7	0.6	0.5	0.4	0.3	0.2	0.2
Far	4.9	9.6	INF	INF	INF	INF	INF	INF	INF	INF	INF
2.5 m Near	1.57	1.4	1.2	1	0.8	0.6	0.5	0.4	0.3	0.2	0.2
Far	6.4	17.2	INF	INF	INF	INF	INF	INF	INF	INF	INF
2.75 m Near	1.7	1.4	1.2	1	0.8	0.6	0.5	0.4	0.3	0.2	0.2
Far	8.4	49.2	INF	INF	INF	INF	INF	INF	INF	INF	INF
3 m Near	1.7	1.5	1.2	1	0.8	0.6	0.5	0.4	0.3	0.2	0.2
Far	11.3	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
3.5 m Near	1.9	1.6	1.3	1.1	0.8	0.6	0.5	0.4	0.3	0.2	0.2
Far	25.1	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
4 m Near	2	1.7	1.4	1.1	0.8	0.7	0.5	0.4	0.3	0.2	0.2
Far	316	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
4.5 m Near	2.2	1.8	1.4	1.1	0.9	0.7	0.5	0.4	0.3	0.2	0.2
Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
5 m Near	2.3	1.9	1.5	1.2	0.9	0.7	0.5	0.4	0.3	0.2	0.2
Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
6 m Near	2.4	2	1.5	1.2	0.9	0.7	0.5	0.4	0.3	0.2	0.2
Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
8 m Near	2.7	2.2	1.6	1.3	0.9	0.7	0.5	0.4	0.3	0.2	0.2
Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
10 m Near	2.9	2.3	1.7	1.3	1	0.7	0.5	0.4	0.3	0.2	0.2
Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Metric

17mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	12m	8m	6m	4m	3m	2m	1.5m	1m	0.8m	0.6m	0.5m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.928	0.902	0.866	0.822	0.76	0.7	0.62	0.5	0.5	0.4	0.3
	Far	1.094	1.123	1.186	1.283	1.5	1.8	2.8	9.9	INF	INF	INF
1.2 m	Near	1.096	1.059	1.009	0.95	0.87	0.79	0.69	0.6	0.5	0.4	0.3
	Far	1.327	1.386	1.485	1.6	2	2.6	5.7	INF	INF	INF	INF
1.4 m	Near	1.259	1.21	1.14	1.07	0.97	0.87	0.7	0.6	0.5	0.4	0.3
	Far	1.578	1.663	1.8	2.1	2.6	4	20.6	INF	INF	INF	INF
1.6 m	Near	1.417	1.36	1.27	1.18	1.06	0.9	0.8	0.7	0.5	0.4	0.3
	Far	1.84	2	2.2	2.5	3.4	6.3	INF	INF	INF	INF	INF
1.8 m	Near	1.57	1.49	1.39	1.28	1.14	1	0.8	0.7	0.6	0.5	0.3
	Far	2.1	2.3	2.6	3.1	4.5	11.6	INF	INF	INF	INF	INF
2 m	Near	1.72	1.63	1.51	1.37	1.21	1.1	0.9	0.7	0.6	0.5	0.4
	Far	2.4	2.6	3	3.7	6	35.4	INF	INF	INF	INF	INF
2.25 m	Near	1.9	1.79	1.64	1.49	1.3	1.1	0.9	0.8	0.6	0.5	0.4
	Far	2.8	3	3.6	4.8	9.3	INF	INF	INF	INF	INF	INF
2.5 m	Near	2.07	1.94	1.77	1.59	1.4	1.2	1	0.8	0.6	0.5	0.4
	Far	3.2	3.5	4.3	6.1	16.1	INF	INF	INF	INF	INF	INF
2.75 m	Near	2.24	2.08	1.89	1.7	1.4	1.2	1	0.8	0.6	0.5	0.4
	Far	3.6	4.1	5.1	7.9	41.1	INF	INF	INF	INF	INF	INF
3 m	Near	2.4	2.22	2	1.8	1.5	1.3	1	0.8	0.6	0.5	0.4
	Far	4	4.6	6.1	10.4	INF	INF	INF	INF	INF	INF	INF
3.5 m	Near	2.71	2.48	2.2	1.9	1.6	1.3	1.1	0.9	0.6	0.5	0.4
	Far	5	6	8.6	21	INF	INF	INF	INF	INF	INF	INF
4 m	Near	2.99	2.72	2.4	2.1	1.7	1.4	1.1	0.9	0.7	0.5	0.4
	Far	6.1	7.6	12.5	91.2	INF	INF	INF	INF	INF	INF	INF
4.5 m	Near	3.26	2.9	2.6	2.2	1.8	1.5	1.1	0.9	0.7	0.5	0.4
	Far	7.3	9.7	19.4	INF	INF	INF	INF	INF	INF	INF	INF
5 m	Near	3.5	3.1	2.7	2.3	1.9	1.5	1.2	0.9	0.7	0.5	0.4
	Far	8.7	12.4	34.5	INF	INF	INF	INF	INF	INF	INF	INF
6 m	Near	4	3.5	3	2.5	2	1.6	1.2	0.9	0.7	0.5	0.4
	Far	12.3	21.3	INF	INF	INF	INF	INF	INF	INF	INF	INF
8 m	Near	4.8	4.1	3.4	2.8	2.2	1.7	1.3	1	0.7	0.5	0.4
	Far	25.5	213	INF	INF	INF	INF	INF	INF	INF	INF	INF
10 m	Near	5.4	4.6	3.7	3	2.3	1.8	1.3	1	0.7	0.5	0.4
	Far	71.5	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF
20 m	Near	7.4	5.9	4.5	3.5	2.6	1.9	1.4	1	0.7	0.6	0.4
	Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Metric

20mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		

Hyperfocal dist'	16m	11m	8m	6m	4m	3m	2m	1.5m	1m	0.7m	0.5m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.947	0.927	0.899	0.865	0.818	0.76	0.69	0.62	0.5	0.5	0.4
	Far	1.066	1.086	1.128	1.189	1.295	1.5	1.9	2.8	19.1	INF	INF
1.2 m	Near	1.123	1.095	1.055	1.007	0.94	0.87	0.78	0.69	0.6	0.5	0.4
	Far	1.289	1.328	1.393	1.489	1.7	2	2.8	5.5	INF	INF	INF
1.4 m	Near	1.295	1.257	1.205	1.14	1.06	0.97	0.86	0.8	0.6	0.5	0.4
	Far	1.524	1.580	1.674	1.8	2.1	2.6	4.2	18.8	INF	INF	INF
1.6 m	Near	1.463	1.415	1.35	1.27	1.17	1.05	0.9	0.8	0.7	0.5	0.4
	Far	1.766	1.843	2	2.2	2.6	3.4	6.9	INF	INF	INF	INF
1.8 m	Near	1.627	1.57	1.49	1.39	1.27	1.14	1	0.8	0.7	0.6	0.4
	Far	2.014	2.1	2.3	2.6	3.2	4.6	14.1	INF	INF	INF	INF
2 m	Near	1.788	1.72	1.62	1.5	1.36	1.21	1	0.9	0.7	0.6	0.4
	Far	2.270	2.4	2.6	3	3.9	6.2	78.1	INF	INF	INF	INF
2.25 m	Near	1.98	1.89	1.78	1.64	1.47	1.3	1.1	0.9	0.7	0.6	0.5
	Far	2.6	2.8	3.1	3.6	4.9	9.6	INF	INF	INF	INF	INF
2.5 m	Near	2.17	2.07	1.93	1.76	1.57	1.4	1.2	1	0.8	0.6	0.5
	Far	2.9	3.2	3.6	4.3	6.4	17.2	INF	INF	INF	INF	INF
2.75 m	Near	2.36	2.23	2.07	1.88	1.7	1.4	1.2	1	0.8	0.6	0.5
	Far	3.3	3.6	4.1	5.2	8.4	49.2	INF	INF	INF	INF	INF
3 m	Near	2.54	2.39	2.21	2	1.7	1.5	1.2	1	0.8	0.6	0.5
	Far	3.7	4	4.7	6.1	11.3	INF	INF	INF	INF	INF	INF
3.5 m	Near	2.89	2.7	2.46	2.2	1.9	1.6	1.3	1.1	0.8	0.7	0.5
	Far	4.4	5	6.1	8.8	25.1	INF	INF	INF	INF	INF	INF
4 m	Near	3.22	2.99	2.7	2.4	2	1.7	1.4	1.1	0.8	0.7	0.5
	Far	5.3	6.1	7.9	12.8	316	INF	INF	INF	INF	INF	INF
4.5 m	Near	3.53	3.25	2.9	2.6	2.2	1.8	1.4	1.1	0.9	0.7	0.5
	Far	6.2	7.3	10.1	20.2	INF	INF	INF	INF	INF	INF	INF
5 m	Near	3.83	3.5	3.1	2.7	2.3	1.9	1.5	1.2	0.9	0.7	0.5
	Far	7.2	8.8	13	37.1	INF	INF	INF	INF	INF	INF	INF
6 m	Near	4.4	4	3.5	3	2.4	2	1.5	1.2	0.9	0.7	0.5
	Far	9.5	12.5	23.3	INF	INF	INF	INF	INF	INF	INF	INF
8 m	Near	5.4	4.7	4	3.4	2.7	2.2	1.6	1.3	0.9	0.7	0.5
	Far	15.9	26.2	1272	INF	INF	INF	INF	INF	INF	INF	INF
10 m	Near	6.2	5.4	4.5	3.7	2.9	2.3	1.7	1.3	1	0.7	0.5
	Far	26.4	76.9	INF	INF	INF	INF	INF	INF	INF	INF	INF
20 m	Near	8.9	7.3	5.8	4.5	3.4	2.5	1.9	1.4	1	0.8	0.5
	Far	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Metric

25mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	25m	18m	13m	9m	6m	4m	3m	2m	1.6m	1.1m	0.8m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.965	0.952	0.933	0.909	0.875	0.833	0.78	0.72	0.64	0.6	0.5
	Far	1.041	1.053	1.078	1.113	1.170	1.256	1.4	1.7	2.5	5.9	INF
1.2 m	Near	1.149	1.13	1.103	1.069	1.021	0.96	0.89	0.81	0.71	0.6	0.5
	Far	1.255	1.279	1.316	1.37	1.459	1.6	1.9	2.4	4.4	INF	INF
1.4 m	Near	1.331	1.305	1.268	1.223	1.16	1.09	0.99	0.9	0.8	0.7	0.5
	Far	1.477	1.510	1.563	1.640	1.8	2	2.4	3.4	10	INF	INF
1.6 m	Near	1.51	1.476	1.429	1.37	1.29	1.2	1.09	0.97	0.8	0.7	0.6
	Far	1.702	1.747	1.819	1.9	2.1	2.4	3.1	4.9	186	INF	INF
1.8 m	Near	1.686	1.644	1.585	1.51	1.42	1.31	1.17	1	0.9	0.7	0.6
	Far	1.931	1.990	2.084	2.2	2.5	2.9	4	7.7	INF	INF	INF
2 m	Near	1.859	1.808	1.74	1.65	1.54	1.41	1.25	1.1	0.9	0.8	0.6
	Far	2.165	2.239	2.4	2.5	2.9	3.5	5.2	13.8	INF	INF	INF
2.25 m	Near	2.072	2.01	1.92	1.82	1.68	1.52	1.3	1.2	1	0.8	0.6
	Far	2.462	2.6	2.7	3	3.4	4.4	7.5	68.6	INF	INF	INF
2.5 m	Near	2.281	2.2	2.1	1.97	1.81	1.63	1.4	1.2	1	0.8	0.6
	Far	2.766	2.9	3.1	3.4	4.1	5.5	11.4	INF	INF	INF	INF
2.75 m	Near	2.49	2.4	2.27	2.12	1.94	1.7	1.5	1.3	1	0.8	0.7
	Far	3.1	3.2	3.5	3.9	4.8	6.9	19.9	INF	INF	INF	INF
3 m	Near	2.69	2.58	2.44	2.27	2.05	1.8	1.6	1.3	1.1	0.9	0.7
	Far	3.4	3.6	3.9	4.5	5.6	8.7	52.7	INF	INF	INF	INF
3.5 m	Near	3.08	2.94	2.75	2.54	2.3	2	1.7	1.4	1.1	0.9	0.7
	Far	4.1	4.3	4.8	5.7	7.8	15.2	INF	INF	INF	INF	INF
4 m	Near	3.46	3.28	3.05	2.79	2.5	2.1	1.8	1.5	1.2	0.9	0.7
	Far	4.7	5.1	5.8	7.1	10.8	34.4	INF	INF	INF	INF	INF
4.5 m	Near	3.83	3.61	3.33	3	2.6	2.3	1.9	1.6	1.2	1	0.7
	Far	5.5	6	7	8.9	15.5	1418	INF	INF	INF	INF	INF
5 m	Near	4.18	3.93	3.6	3.2	2.8	2.4	2	1.6	1.2	1	0.7
	Far	6.2	6.9	8.2	11.2	23.8	INF	INF	INF	INF	INF	INF
6 m	Near	4.86	4.51	4.1	3.6	3.1	2.6	2.1	1.7	1.3	1	0.7
	Far	7.9	9	11.4	17.9	124	INF	INF	INF	INF	INF	INF
8 m	Near	6.1	5.6	4.9	4.3	3.5	2.9	2.3	1.8	1.4	1	0.8
	Far	11.7	14.4	21.9	72.6	INF	INF	INF	INF	INF	INF	INF
10 m	Near	7.2	6.4	5.6	4.8	3.9	3.1	2.4	1.9	1.4	1.1	0.8
	Far	16.6	22.5	48.8	INF	INF	INF	INF	INF	INF	INF	INF
20 m	Near	11.1	9.5	7.7	6.2	4.8	3.7	2.8	2.1	1.5	1.1	0.8
	Far	98.8	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Metric

30mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	36m	26m	18m	13m	9m	6m	5m	3m	2m	1.6m	1.1m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.976	0.966	0.952	0.935	0.909	0.878	0.834	0.79	0.72	0.65	0.6
	Far	1.028	1.036	1.052	1.075	1.112	1.164	1.254	1.4	1.7	2.3	6.2
1.2 m	Near	1.164	1.151	1.131	1.106	1.07	1.026	0.97	0.9	0.81	0.73	0.6
	Far	1.237	1.253	1.278	1.313	1.368	1.450	1.6	1.8	2.4	3.9	INF
1.4 m	Near	1.351	1.333	1.306	1.272	1.224	1.17	1.09	1.01	0.89	0.8	0.7
	Far	1.452	1.474	1.509	1.558	1.638	1.8	2	2.3	3.4	7.8	INF
1.6 m	Near	1.536	1.512	1.477	1.433	1.37	1.3	1.2	1.1	0.97	0.8	0.7
	Far	1.669	1.699	1.746	1.812	1.9	2.1	2.4	3	5	29.5	INF
1.8 m	Near	1.719	1.688	1.645	1.59	1.52	1.43	1.31	1.19	1	0.9	0.7
	Far	1.889	1.927	1.988	2.075	2.2	2.5	2.9	3.8	7.9	INF	INF
2 m	Near	1.9	1.863	1.809	1.74	1.65	1.55	1.41	1.27	1.1	0.9	0.8
	Far	2.111	2.16	2.236	2.3	2.5	2.8	3.5	4.9	14.7	INF	INF
2.25 m	Near	2.123	2.077	2.01	1.93	1.82	1.69	1.53	1.4	1.2	1	0.8
	Far	2.393	2.455	2.6	2.7	3	3.4	4.4	6.8	99.1	INF	INF
2.5 m	Near	2.344	2.287	2.21	2.11	1.98	1.82	1.64	1.5	1.2	1	0.8
	Far	2.678	2.758	2.9	3.1	3.4	4	5.4	9.8	INF	INF	INF
2.75 m	Near	2.562	2.49	2.4	2.28	2.13	1.95	1.7	1.5	1.3	1.1	0.8
	Far	2.968	3.1	3.2	3.5	3.9	4.7	6.8	15.5	INF	INF	INF
3 m	Near	2.777	2.7	2.58	2.45	2.27	2.07	1.8	1.6	1.3	1.1	0.9
	Far	3.263	3.4	3.6	3.9	4.4	5.5	8.6	29.9	INF	INF	INF
3.5 m	Near	3.2	3.09	2.95	2.77	2.54	2.3	2	1.7	1.4	1.2	0.9
	Far	3.9	4	4.3	4.8	5.6	7.5	14.8	INF	INF	INF	INF
4 m	Near	3.61	3.47	3.29	3.07	2.8	2.5	2.2	1.8	1.5	1.2	0.9
	Far	4.5	4.7	5.1	5.8	7.1	10.3	32.4	INF	INF	INF	INF
4.5 m	Near	4.01	3.84	3.62	3.36	3	2.7	2.3	1.9	1.5	1.2	0.9
	Far	5.1	5.4	6	6.9	8.9	14.5	400	INF	INF	INF	INF
5 m	Near	4.4	4.2	3.93	3.62	3.2	2.8	2.4	2	1.6	1.3	1
	Far	5.8	6.2	6.9	8.1	11.1	21.6	INF	INF	INF	INF	INF
6 m	Near	5.16	4.88	4.52	4.1	3.6	3.1	2.6	2.2	1.7	1.3	1
	Far	7.2	7.8	8.9	11.1	17.6	79.9	INF	INF	INF	INF	INF
8 m	Near	6.56	6.1	5.6	5	4.3	3.6	2.9	2.4	1.8	1.4	1
	Far	10.3	11.6	14.3	20.9	68.2	INF	INF	INF	INF	INF	INF
10 m	Near	7.8	7.2	6.5	5.7	4.8	4	3.1	2.5	1.9	1.5	1.1
	Far	13.8	16.3	22.3	44.1	INF	INF	INF	INF	INF	INF	INF
20 m	Near	12.9	11.3	9.5	7.9	6.3	4.9	3.7	2.9	2.1	1.6	1.1
	Far	44.8	89	INF	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Metric

35mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	49m	35m	25m	18m	12m	9m	6m	4m	3m	2m	1.5m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.982	0.975	0.965	0.951	0.932	0.907	0.872	0.833	0.78	0.72	0.64
	Far	1.020	1.026	1.038	1.054	1.079	1.115	1.174	1.257	1.4	1.7	2.6
1.2 m	Near	1.174	1.163	1.148	1.129	1.101	1.066	1.018	0.96	0.89	0.81	0.71
	Far	1.227	1.239	1.256	1.280	1.319	1.374	1.465	1.6	1.9	2.4	4.7
1.4 m	Near	1.364	1.35	1.329	1.303	1.266	1.22	1.16	1.09	0.99	0.89	0.8
	Far	1.438	1.454	1.478	1.512	1.567	1.646	1.8	2	2.5	3.5	11.5
1.6 m	Near	1.552	1.534	1.508	1.474	1.426	1.37	1.29	1.2	1.08	0.96	0.8
	Far	1.650	1.671	1.704	1.750	1.824	1.9	2.1	2.4	3.2	5.1	INF
1.8 m	Near	1.74	1.717	1.683	1.641	1.58	1.51	1.41	1.31	1.16	1	0.9
	Far	1.864	1.892	1.934	1.994	2.1	2.2	2.5	2.9	4.1	8.2	INF
2 m	Near	1.925	1.897	1.856	1.804	1.73	1.64	1.53	1.41	1.24	1.1	0.9
	Far	2.080	2.115	2.168	2.244	2.4	2.6	2.9	3.5	5.4	15.7	INF
2.25 m	Near	2.155	2.12	2.069	2	1.92	1.81	1.67	1.52	1.3	1.2	1
	Far	2.353	2.397	2.467	2.6	2.7	3	3.5	4.4	7.9	181	INF
2.5 m	Near	2.383	2.34	2.277	2.2	2.09	1.96	1.8	1.63	1.4	1.2	1
	Far	2.628	2.684	2.772	2.9	3.1	3.5	4.1	5.5	12.3	INF	INF
2.75 m	Near	2.609	2.557	2.48	2.39	2.26	2.11	1.92	1.7	1.5	1.3	1
	Far	2.907	2.975	3.1	3.2	3.5	4	4.9	6.9	22.8	INF	INF
3 m	Near	2.832	2.77	2.68	2.57	2.43	2.26	2.04	1.8	1.6	1.3	1.1
	Far	3.189	3.3	3.4	3.6	3.9	4.5	5.7	8.8	80	INF	INF
3.5 m	Near	3.273	3.19	3.07	2.93	2.74	2.52	2.3	2	1.7	1.4	1.1
	Far	3.761	3.9	4.1	4.3	4.9	5.7	7.9	15.3	INF	INF	INF
4 m	Near	3.71	3.6	3.45	3.27	3.04	2.77	2.5	2.1	1.8	1.5	1.2
	Far	4.3	4.5	4.8	5.2	5.9	7.3	11.2	34.9	INF	INF	INF
4.5 m	Near	4.13	4	3.82	3.6	3.31	3	2.6	2.3	1.9	1.5	1.2
	Far	4.9	5.1	5.5	6	7	9.1	16.3	3965	INF	INF	INF
5 m	Near	4.55	4.39	4.17	3.91	3.58	3.2	2.8	2.4	1.9	1.6	1.2
	Far	5.6	5.8	6.3	7	8.4	11.4	25.9	INF	INF	INF	INF
6 m	Near	5.36	5.14	4.84	4.49	4.1	3.6	3.1	2.6	2.1	1.7	1.3
	Far	6.8	7.2	7.9	9.1	11.6	18.6	208	INF	INF	INF	INF
8 m	Near	6.89	6.53	6.1	5.5	4.9	4.2	3.5	2.9	2.3	1.8	1.3
	Far	9.5	10.3	11.8	14.6	22.7	87	INF	INF	INF	INF	INF
10 m	Near	8.32	7.8	7.1	6.4	5.5	4.7	3.8	3.1	2.4	1.9	1.4
	Far	12.5	14	16.8	23.1	53	INF	INF	INF	INF	INF	INF
20 m	Near	14.2	12.8	11	9.4	7.6	6.1	4.7	3.7	2.7	2.1	1.5
	Far	33.7	46.4	107	INF	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Metric

40mm

Circle of Confusion		Aperture										
0.05mm					1.4	2	2.8	4	5.6	8	11	16
0.037mm				1.4	2	2.8	4	5.6	8	11	16	22
0.025mm			1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm		1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		64m	46m	32m	23m	16m	11m	8m	6m	4m	3m	2m
Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.986	0.981	0.973	0.962	0.947	0.927	0.899	0.867	0.818	0.77	0.69
	Far	1.015	1.020	1.029	1.041	1.06	1.086	1.128	1.185	1.295	1.5	1.9
1.2 m	Near	1.18	1.172	1.16	1.145	1.123	1.095	1.055	1.01	0.94	0.87	0.78
	Far	1.221	1.229	1.242	1.260	1.289	1.328	1.393	1.483	1.7	2	2.8
1.4 m	Near	1.372	1.361	1.345	1.325	1.295	1.257	1.205	1.15	1.06	0.97	0.86
	Far	1.429	1.441	1.459	1.484	1.524	1.580	1.674	1.8	2.1	2.6	4.2
1.6 m	Near	1.563	1.549	1.528	1.502	1.463	1.415	1.35	1.27	1.17	1.06	0.9
	Far	1.638	1.654	1.678	1.712	1.766	1.843	2	2.2	2.6	3.4	6.9
1.8 m	Near	1.753	1.735	1.709	1.676	1.627	1.57	1.49	1.4	1.27	1.14	1
	Far	1.849	1.869	1.901	1.945	2.014	2.1	2.3	2.6	3.2	4.4	14.1
2 m	Near	1.942	1.92	1.888	1.847	1.788	1.72	1.62	1.51	1.36	1.22	1
	Far	2.061	2.086	2.126	2.181	2.270	2.4	2.6	3	3.9	6	78.1
2.25 m	Near	2.177	2.149	2.108	2.057	1.98	1.89	1.78	1.65	1.47	1.3	1.1
	Far	2.328	2.361	2.412	2.484	2.6	2.8	3.1	3.6	4.9	9.1	INF
2.5 m	Near	2.41	2.375	2.326	2.26	2.17	2.07	1.93	1.77	1.57	1.4	1.2
	Far	2.597	2.638	2.703	2.8	2.9	3.2	3.6	4.3	6.4	15.6	INF
2.75 m	Near	2.641	2.599	2.54	2.46	2.36	2.23	2.07	1.89	1.7	1.5	1.2
	Far	2.868	2.919	2.998	3.1	3.3	3.6	4.1	5.1	8.4	37.6	INF
3 m	Near	2.87	2.821	2.75	2.66	2.54	2.39	2.21	2.01	1.7	1.5	1.2
	Far	3.142	3.203	3.3	3.4	3.7	4	4.7	6	11.3	INF	INF
3.5 m	Near	3.324	3.26	3.16	3.05	2.89	2.7	2.46	2.2	1.9	1.6	1.3
	Far	3.696	3.8	3.9	4.1	4.4	5	6.1	8.5	25.1	INF	INF
4 m	Near	3.77	3.69	3.57	3.42	3.22	2.99	2.7	2.4	2	1.7	1.4
	Far	4.259	4.4	4.6	4.8	5.3	6.1	7.9	12.4	316	INF	INF
4.5 m	Near	4.21	4.11	3.96	3.77	3.53	3.25	2.9	2.6	2.2	1.8	1.4
	Far	4.8	5	5.2	5.6	6.2	7.3	10.1	19	INF	INF	INF
5 m	Near	4.64	4.52	4.34	4.12	3.83	3.5	3.1	2.7	2.3	1.9	1.5
	Far	5.4	5.6	5.9	6.4	7.2	8.8	13	33.2	INF	INF	INF
6 m	Near	5.49	5.31	5.07	4.77	4.4	4	3.5	3	2.4	2	1.5
	Far	6.6	6.9	7.4	8.1	9.5	12.5	23.3	INF	INF	INF	INF
8 m	Near	7.12	6.82	6.42	5.9	5.4	4.7	4	3.4	2.7	2.2	1.6
	Far	9.1	9.7	10.6	12.2	15.9	26.2	1272	INF	INF	INF	INF
10 m	Near	8.66	8.22	7.6	7	6.2	5.4	4.5	3.7	2.9	2.3	1.7
	Far	11.8	12.8	14.5	17.7	26.4	76.9	INF	INF	INF	INF	INF
20 m	Near	15.3	13.9	12.3	10.7	8.9	7.3	5.8	4.6	3.4	2.6	1.9
	Far	29	35.4	53	156	INF	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Metric

50mm

Circle of Confusion		Aperture										
0.05mm					1.4	2	2.8	4	5.6	8	11	16
0.037mm				1.4	2	2.8	4	5.6	8	11	16	22
0.025mm			1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm		1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		100m	71m	50m	36m	25m	18m	13m	9m	6m	5m	3m
Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.991	0.988	0.982	0.975	0.965	0.952	0.933	0.91	0.875	0.836	0.78
	Far	1.010	1.012	1.018	1.026	1.037	1.053	1.078	1.110	1.170	1.251	1.4
1.2 m	Near	1.187	1.182	1.174	1.164	1.149	1.13	1.103	1.071	1.021	0.97	0.89
	Far	1.213	1.218	1.227	1.238	1.255	1.279	1.316	1.366	1.459	1.6	1.9
1.4 m	Near	1.382	1.375	1.365	1.351	1.331	1.305	1.268	1.225	1.16	1.09	0.99
	Far	1.418	1.426	1.437	1.453	1.477	1.510	1.563	1.635	1.8	2	2.4
1.6 m	Near	1.576	1.567	1.553	1.536	1.51	1.476	1.429	1.37	1.29	1.21	1.09
	Far	1.624	1.634	1.649	1.670	1.702	1.747	1.819	1.9	2.1	2.4	3.1
1.8 m	Near	1.77	1.758	1.741	1.718	1.686	1.644	1.585	1.52	1.42	1.31	1.17
	Far	1.831	1.844	1.863	1.890	1.931	1.990	2.084	2.2	2.5	2.9	4
2 m	Near	1.963	1.948	1.927	1.899	1.859	1.808	1.74	1.66	1.54	1.41	1.25
	Far	2.038	2.054	2.079	2.112	2.165	2.239	2.4	2.5	2.9	3.5	5.2
2.25 m	Near	2.203	2.184	2.157	2.122	2.072	2.01	1.92	1.82	1.68	1.53	1.3
	Far	2.299	2.319	2.351	2.394	2.462	2.6	2.7	3	3.4	4.3	7.5
2.5 m	Near	2.441	2.419	2.386	2.343	2.281	2.2	2.1	1.98	1.81	1.64	1.4
	Far	2.561	2.587	2.626	2.680	2.766	2.9	3.1	3.4	4.1	5.4	11.4
2.75 m	Near	2.679	2.652	2.612	2.56	2.49	2.4	2.27	2.13	1.94	1.74	1.5
	Far	2.824	2.856	2.904	2.970	3.1	3.2	3.5	3.9	4.8	6.7	19.9
3 m	Near	2.915	2.883	2.836	2.775	2.69	2.58	2.44	2.28	2.05	1.8	1.6
	Far	3.089	3.127	3.185	3.265	3.4	3.6	3.9	4.4	5.6	8.5	52.7
3.5 m	Near	3.385	3.341	3.277	3.2	3.08	2.94	2.75	2.55	2.3	2	1.7
	Far	3.623	3.675	3.755	3.9	4.1	4.3	4.8	5.6	7.8	14.4	INF
4 m	Near	3.85	3.793	3.71	3.61	3.46	3.28	3.05	2.8	2.5	2.2	1.8
	Far	4.162	4.231	4.3	4.5	4.7	5.1	5.8	7	10.8	30.2	INF
4.5 m	Near	4.31	4.24	4.14	4.01	3.83	3.61	3.33	3	2.6	2.3	1.9
	Far	4.707	4.8	4.9	5.1	5.5	6	7	8.8	15.5	212	INF
5 m	Near	4.767	4.68	4.55	4.4	4.18	3.93	3.6	3.3	2.8	2.4	2
	Far	5.257	5.4	5.5	5.8	6.2	6.9	8.2	10.9	23.8	INF	INF
6 m	Near	5.67	5.54	5.37	5.15	4.86	4.51	4.1	3.6	3.1	2.6	2.1
	Far	6.4	6.5	6.8	7.2	7.9	9	11.4	17.3	124	INF	INF
8 m	Near	7.41	7.2	6.91	6.55	6.1	5.6	4.9	4.3	3.5	2.9	2.3
	Far	8.7	9	9.5	10.3	11.7	14.4	21.9	63.4	INF	INF	INF
10 m	Near	9.1	8.78	8.35	7.8	7.2	6.4	5.6	4.8	3.9	3.2	2.4
	Far	11.1	11.6	12.5	13.8	16.6	22.5	48.8	INF	INF	INF	INF
20 m	Near	16.7	15.6	14.3	12.8	11.1	9.5	7.7	6.3	4.8	3.8	2.8
	Far	25	27.7	33.2	45.2	98.8	INF	INF	INF	INF	INF	INF

DEPTH OF FIELD
Metric

75mm

Circle of Confusion		Aperture										
0.05mm					1.4	2	2.8	4	5.6	8	11	16
0.037mm				1.4	2	2.8	4	5.6	8	11	16	22
0.025mm			1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm		1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		225m	161m	113m	80m	56m	40m	28m	20m	14m	10m	7m
Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.996	0.994	0.992	0.989	0.984	0.978	0.969	0.958	0.94	0.919	0.887
	Far	1.004	1.005	1.008	1.011	1.016	1.023	1.033	1.046	1.068	1.097	1.148
1.2 m	Near	1.194	1.192	1.188	1.184	1.177	1.168	1.155	1.139	1.113	1.084	1.038
	Far	1.205	1.208	1.211	1.216	1.224	1.233	1.249	1.268	1.302	1.345	1.424
1.4 m	Near	1.392	1.389	1.384	1.378	1.368	1.356	1.338	1.316	1.282	1.243	1.18
	Far	1.408	1.411	1.416	1.423	1.433	1.446	1.468	1.495	1.543	1.605	1.7
1.6 m	Near	1.589	1.585	1.579	1.571	1.558	1.542	1.519	1.491	1.446	1.396	1.32
	Far	1.610	1.615	1.621	1.630	1.643	1.662	1.690	1.727	1.792	1.876	2
1.8 m	Near	1.786	1.781	1.773	1.763	1.747	1.727	1.697	1.662	1.606	1.54	1.45
	Far	1.813	1.819	1.827	1.839	1.856	1.879	1.916	1.963	2.048	2.2	2.4
2 m	Near	1.983	1.977	1.967	1.954	1.935	1.91	1.874	1.83	1.76	1.69	1.58
	Far	2.017	2.024	2.034	2.048	2.07	2.099	2.145	2.205	2.3	2.5	2.7
2.25 m	Near	2.229	2.22	2.208	2.191	2.167	2.136	2.09	2.036	1.95	1.86	1.73
	Far	2.271	2.280	2.293	2.311	2.339	2.377	2.436	2.515	2.7	2.9	3.3
2.5 m	Near	2.474	2.463	2.448	2.428	2.398	2.359	2.304	2.24	2.14	2.03	1.87
	Far	2.527	2.537	2.554	2.577	2.611	2.659	2.733	2.8	3	3.3	3.8
2.75 m	Near	2.718	2.705	2.687	2.662	2.626	2.58	2.51	2.44	2.32	2.19	2
	Far	2.782	2.796	2.816	2.843	2.886	2.944	3	3.2	3.4	3.7	4.4
3 m	Near	2.962	2.947	2.925	2.896	2.853	2.798	2.72	2.63	2.49	2.34	2.13
	Far	3.039	3.055	3.079	3.112	3.163	3.233	3.3	3.5	3.8	4.2	5.1
3.5 m	Near	3.448	3.427	3.397	3.358	3.301	3.23	3.12	3	2.82	2.63	2.36
	Far	3.553	3.575	3.609	3.654	3.725	3.8	4	4.2	4.6	5.3	6.8
4 m	Near	3.932	3.905	3.866	3.815	3.74	3.65	3.51	3.36	3.13	2.9	2.6
	Far	4.070	4.099	4.143	4.204	4.3	4.4	4.6	4.9	5.5	6.5	9.1
4.5 m	Near	4.414	4.38	4.331	4.266	4.17	4.06	3.89	3.7	3.43	3.15	2.8
	Far	4.589	4.626	4.683	4.760	4.9	5.1	5.3	5.7	6.6	7.9	12.2
5 m	Near	4.893	4.852	4.791	4.71	4.6	4.46	4.26	4.04	3.71	3.4	3
	Far	5.111	5.157	5.227	5.3	5.5	5.7	6.1	6.6	7.7	9.6	16.8
6 m	Near	5.847	5.788	5.7	5.59	5.43	5.23	4.96	4.66	4.2	3.8	3.3
	Far	6.161	6.228	6.3	6.5	6.7	7	7.6	8.4	10.4	14.3	38.7
8 m	Near	7.73	7.63	7.48	7.28	7.02	6.69	6.25	5.8	5.1	4.5	3.8
	Far	8.3	8.4	8.6	8.9	9.3	10	11.1	13.1	18.3	35.8	INF
10 m	Near	9.58	9.42	9.19	8.9	8.5	8	7.4	6.7	5.9	5.1	4.2
	Far	10.5	10.7	11	11.4	12.1	13.3	15.4	19.4	34.1	367	INF
20 m	Near	18.38	17.8	17	16	14.8	13.4	11.7	10.1	8.3	6.8	5.2
	Far	21.9	22.8	24.3	26.6	31	39.7	68.7	808	INF	INF	INF

DEPTH OF FIELD
Metric

100mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		

Hyperfocal dist'	400m	286m	200m	143m	100m	71m	50m	36m	25m	18m	13m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.998	0.997	0.996	0.994	0.991	0.988	0.982	0.976	0.965	0.953	0.933
	Far	1.002	1.003	1.004	1.006	1.009	1.012	1.018	1.025	1.037	1.052	1.078
1.2 m	Near	1.197	1.195	1.193	1.191	1.187	1.182	1.174	1.165	1.149	1.132	1.103
	Far	1.203	1.204	1.206	1.209	1.213	1.218	1.227	1.237	1.255	1.277	1.316
1.4 m	Near	1.395	1.394	1.391	1.387	1.382	1.375	1.365	1.352	1.331	1.307	1.268
	Far	1.404	1.406	1.409	1.412	1.418	1.426	1.437	1.452	1.477	1.508	1.563
1.6 m	Near	1.594	1.592	1.588	1.583	1.576	1.567	1.553	1.537	1.51	1.478	1.429
	Far	1.606	1.608	1.612	1.617	1.624	1.634	1.649	1.669	1.702	1.744	1.819
1.8 m	Near	1.792	1.789	1.785	1.779	1.77	1.758	1.741	1.72	1.686	1.646	1.585
	Far	1.807	1.810	1.815	1.821	1.831	1.844	1.863	1.888	1.931	1.986	2.084
2 m	Near	1.991	1.987	1.981	1.974	1.963	1.948	1.927	1.901	1.859	1.811	1.74
	Far	2.009	2.013	2.019	2.027	2.038	2.054	2.079	2.110	2.165	2.234	2.4
2.25 m	Near	2.238	2.233	2.226	2.217	2.203	2.184	2.157	2.124	2.072	2.01	1.92
	Far	2.262	2.267	2.274	2.284	2.299	2.319	2.351	2.391	2.462	2.6	2.7
2.5 m	Near	2.485	2.479	2.47	2.459	2.441	2.419	2.386	2.345	2.281	2.21	2.1
	Far	2.515	2.521	2.530	2.542	2.561	2.587	2.626	2.677	2.766	2.9	3.1
2.75 m	Near	2.732	2.725	2.714	2.7	2.679	2.652	2.612	2.563	2.49	2.4	2.27
	Far	2.768	2.775	2.786	2.802	2.824	2.856	2.904	2.966	3.1	3.2	3.5
3 m	Near	2.978	2.97	2.957	2.94	2.915	2.883	2.836	2.779	2.69	2.59	2.44
	Far	3.021	3.030	3.044	3.062	3.089	3.127	3.185	3.260	3.4	3.6	3.9
3.5 m	Near	3.47	3.459	3.441	3.419	3.385	3.341	3.277	3.2	3.08	2.95	2.75
	Far	3.53	3.542	3.560	3.585	3.623	3.675	3.755	3.9	4.1	4.3	4.8
4 m	Near	3.961	3.946	3.923	3.894	3.85	3.793	3.71	3.61	3.46	3.3	3.05
	Far	4.039	4.055	4.079	4.112	4.162	4.231	4.3	4.5	4.7	5.1	5.8
4.5 m	Near	4.451	4.432	4.403	4.366	4.31	4.24	4.14	4.01	3.83	3.63	3.33
	Far	4.550	4.570	4.601	4.643	4.707	4.8	4.9	5.1	5.5	5.9	7
5 m	Near	4.939	4.916	4.88	4.834	4.767	4.68	4.55	4.41	4.18	3.94	3.6
	Far	5.062	5.087	5.125	5.177	5.257	5.4	5.5	5.8	6.2	6.9	8.2
6 m	Near	5.913	5.879	5.828	5.762	5.67	5.54	5.37	5.16	4.86	4.53	4.1
	Far	6.089	6.126	6.182	6.258	6.4	6.5	6.8	7.2	7.9	8.9	11.4
8 m	Near	7.845	7.785	7.7	7.58	7.41	7.2	6.91	6.57	6.1	5.6	4.9
	Far	8.161	8.227	8.3	8.5	8.7	9	9.5	10.2	11.7	14.2	21.9
10 m	Near	9.759	9.67	9.53	9.35	9.1	8.78	8.35	7.9	7.2	6.5	5.6
	Far	10.25	10.4	10.5	10.7	11.1	11.6	12.5	13.7	16.6	22	48.8
20 m	Near	19.05	18.7	18.19	17.6	16.7	15.6	14.3	12.9	11.1	9.6	7.7
	Far	21	21.5	22.2	23.2	25	27.7	33.2	44.2	98.8	INF	INF

DEPTH OF FIELD
Metric

150mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	900m	643m	450m	321m	225m	161m	113m	82m	56m	41m	28m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.999	0.999	0.998	0.997	0.996	0.994	0.992	0.989	0.984	0.978	0.969
	Far	1.001	1.001	1.002	1.002	1.004	1.005	1.008	1.011	1.016	1.022	1.033
1.2 m	Near	1.199	1.198	1.197	1.196	1.194	1.192	1.188	1.184	1.177	1.169	1.155
	Far	1.201	1.202	1.202	1.204	1.205	1.208	1.211	1.216	1.224	1.233	1.249
1.4 m	Near	1.398	1.397	1.396	1.394	1.392	1.389	1.384	1.378	1.368	1.357	1.338
	Far	1.402	1.402	1.404	1.405	1.408	1.411	1.416	1.422	1.433	1.446	1.468
1.6 m	Near	1.597	1.596	1.595	1.593	1.589	1.585	1.579	1.571	1.558	1.543	1.519
	Far	1.602	1.603	1.605	1.607	1.610	1.615	1.621	1.629	1.643	1.661	1.690
1.8 m	Near	1.797	1.795	1.793	1.791	1.786	1.781	1.773	1.763	1.747	1.728	1.697
	Far	1.803	1.804	1.806	1.809	1.813	1.819	1.827	1.838	1.856	1.878	1.916
2 m	Near	1.996	1.994	1.992	1.988	1.983	1.977	1.967	1.955	1.935	1.911	1.874
	Far	2.004	2.005	2.008	2.011	2.017	2.024	2.034	2.047	2.07	2.097	2.145
2.25 m	Near	2.245	2.242	2.239	2.235	2.229	2.22	2.208	2.192	2.167	2.138	2.09
	Far	2.255	2.257	2.260	2.265	2.271	2.280	2.293	2.310	2.339	2.375	2.436
2.5 m	Near	2.493	2.491	2.487	2.481	2.474	2.463	2.448	2.429	2.398	2.362	2.304
	Far	2.506	2.509	2.513	2.518	2.527	2.537	2.554	2.575	2.611	2.656	2.733
2.75 m	Near	2.742	2.739	2.734	2.728	2.718	2.705	2.687	2.664	2.626	2.583	2.51
	Far	2.758	2.761	2.766	2.772	2.782	2.796	2.816	2.842	2.886	2.940	3
3 m	Near	2.99	2.987	2.981	2.973	2.962	2.947	2.925	2.897	2.853	2.802	2.72
	Far	3.009	3.013	3.019	3.027	3.039	3.055	3.079	3.110	3.163	3.229	3.3
3.5 m	Near	3.487	3.482	3.474	3.463	3.448	3.427	3.397	3.36	3.301	3.23	3.12
	Far	3.513	3.518	3.526	3.537	3.553	3.575	3.609	3.651	3.725	3.8	4
4 m	Near	3.983	3.976	3.966	3.952	3.932	3.905	3.866	3.818	3.74	3.65	3.51
	Far	4.017	4.024	4.035	4.049	4.070	4.099	4.143	4.200	4.3	4.4	4.6
4.5 m	Near	4.478	4.469	4.456	4.439	4.414	4.38	4.331	4.27	4.17	4.06	3.89
	Far	4.522	4.531	4.544	4.562	4.589	4.626	4.683	4.756	4.9	5	5.3
5 m	Near	4.973	4.962	4.946	4.925	4.893	4.852	4.791	4.72	4.6	4.47	4.26
	Far	5.027	5.038	5.055	5.077	5.111	5.157	5.227	5.3	5.5	5.7	6.1
6 m	Near	5.961	5.945	5.922	5.892	5.847	5.788	5.7	5.6	5.43	5.24	4.96
	Far	6.039	6.055	6.079	6.112	6.161	6.228	6.3	6.5	6.7	7	7.6
8 m	Near	7.93	7.903	7.862	7.808	7.73	7.63	7.48	7.3	7.02	6.71	6.25
	Far	8.070	8.099	8.143	8.201	8.3	8.4	8.6	8.9	9.3	9.9	11.1
10 m	Near	9.891	9.848	9.785	9.7	9.58	9.42	9.19	8.92	8.5	8.1	7.4
	Far	10.11	10.15	10.22	10.3	10.5	10.7	11	11.4	12.1	13.2	15.4
20 m	Near	19.57	19.4	19.15	18.83	8.38	17.8	17	16.1	14.8	13.5	11.7
	Far	20.5	20.6	20.9	21.3	21.9	22.8	24.3	26.4	31	39	68.7

DEPTH OF FIELD
Metric

200mm

Circle of Confusion		Aperture										
0.05mm					1.4	2	2.8	4	5.6	8	11	16
0.037mm				1.4	2	2.8	4	5.6	8	11	16	22
0.025mm			1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm		1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm		2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'		1600m	1143m	800m	571m	400m	286m	200m	145m	100m	73m	50m
Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	0.999	0.999	0.999	0.998	0.998	0.997	0.996	0.994	0.991	0.988	0.982
	Far	1.000	1.000	1.001	1.001	1.002	1.003	1.004	1.006	1.009	1.012	1.018
1.2 m	Near	1.199	1.199	1.198	1.198	1.197	1.195	1.193	1.191	1.187	1.182	1.174
	Far	1.200	1.201	1.201	1.202	1.203	1.204	1.206	1.209	1.213	1.218	1.227
1.4 m	Near	1.399	1.398	1.398	1.397	1.395	1.394	1.391	1.388	1.382	1.375	1.365
	Far	1.401	1.401	1.402	1.403	1.404	1.406	1.409	1.412	1.418	1.425	1.437
1.6 m	Near	1.598	1.598	1.597	1.596	1.594	1.592	1.588	1.584	1.576	1.568	1.553
	Far	1.601	1.602	1.603	1.604	1.606	1.608	1.612	1.616	1.624	1.633	1.649
1.8 m	Near	1.798	1.797	1.796	1.795	1.792	1.789	1.785	1.779	1.77	1.759	1.741
	Far	1.801	1.802	1.803	1.805	1.807	1.810	1.815	1.821	1.831	1.843	1.863
2 m	Near	1.998	1.997	1.995	1.993	1.991	1.987	1.981	1.974	1.963	1.949	1.927
	Far	2.002	2.003	2.004	2.006	2.009	2.013	2.019	2.026	2.038	2.053	2.079
2.25 m	Near	2.247	2.246	2.244	2.242	2.238	2.233	2.226	2.217	2.203	2.185	2.157
	Far	2.253	2.254	2.256	2.258	2.262	2.267	2.274	2.283	2.299	2.318	2.351
2.5 m	Near	2.496	2.495	2.493	2.49	2.485	2.479	2.47	2.459	2.441	2.42	2.386
	Far	2.503	2.505	2.507	2.510	2.515	2.521	2.530	2.542	2.561	2.585	2.626
2.75m	Near	2.745	2.744	2.741	2.737	2.732	2.725	2.714	2.701	2.679	2.653	2.612
	Far	2.754	2.756	2.759	2.762	2.768	2.775	2.786	2.801	2.824	2.854	2.904
3 m	Near	2.995	2.992	2.989	2.985	2.978	2.97	2.957	2.941	2.915	2.885	2.836
	Far	3.005	3.007	3.010	3.015	3.021	3.030	3.044	3.061	3.089	3.124	3.185
3.5 m	Near	3.493	3.49	3.485	3.479	3.47	3.459	3.441	3.42	3.385	3.344	3.277
	Far	3.507	3.510	3.514	3.521	3.53	3.542	3.560	3.583	3.623	3.671	3.755
4 m	Near	3.99	3.986	3.981	3.973	3.961	3.946	3.923	3.896	3.85	3.797	3.71
	Far	4.009	4.013	4.019	4.027	4.039	4.055	4.079	4.110	4.162	4.226	4.3
4.5 m	Near	4.488	4.483	4.475	4.466	4.451	4.432	4.403	4.368	4.31	4.24	4.14
	Far	4.512	4.517	4.524	4.534	4.550	4.570	4.601	4.640	4.707	4.8	4.9
5 m	Near	4.985	4.979	4.97	4.957	4.939	4.916	4.88	4,837	4.767	4.68	4.55
	Far	5.015	5.021	5.030	5.043	5.062	5.087	5.125	5.174	5.257	5.4	5.5
6 m	Near	5.978	5.969	5.956	5.939	5.913	5.879	5.828	5.766	5.67	5.55	5.37
	Far	6.022	6.031	6.044	6.062	6.089	6.126	6.182	6.253	6.4	6.5	6.8
8 m	Near	7.961	7.945	7.922	7.891	7.845	7.785	7.7	7.59	7.41	7.22	6.91
	Far	8.039	8.055	8.079	8.112	8.161	8.227	8.3	8.5	8.7	9	9.5
10 m	Near	9.939	9.914	9.878	9.83	9.759	9.67	9.53	9.36	9.1	8.8	8.35
	Far	10.06	10.08	10.12	10.17	10.25	10.4	10.5	10.7	11.1	11.6	12.5
20 m	Near	19.75	19.66	19.51	19.33	19.05	18.7	18.19	17.6	16.7	15.7	14.3
	Far	20.25	20.4	20.5	20.7	21	21.5	22.2	23.2	25	27.5	33.2

DEPTH OF FIELD
Metric

250mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	2500m	1786m	1250m	893m	625m	446m	313m	227m	156m	114m	78m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	1	0.999	0.999	0.999	0.999	0.998	0.997	0.996	0.994	0.992	0.989
	Far	1.000	1.000	1.000	1.001	1.001	1.002	1.002	1.004	1.005	1.008	1.011
1.2 m	Near	1.199	1.199	1.199	1.199	1.198	1.197	1.196	1.194	1.192	1.188	1.183
	Far	1.200	1.200	1.201	1.201	1.202	1.203	1.204	1.205	1.208	1.211	1.217
1.4 m	Near	1.399	1.399	1.399	1.398	1.397	1.396	1.394	1.392	1.388	1.384	1.377
	Far	1.400	1.401	1.401	1.402	1.402	1.404	1.405	1.408	1.411	1.416	1.423
1.6 m	Near	1.599	1.599	1.598	1.597	1.596	1.595	1.592	1.59	1.585	1.579	1.57
	Far	1.601	1.601	1.601	1.602	1.603	1.605	1.607	1.610	1.615	1.621	1.631
1.8 m	Near	1.799	1.798	1.798	1.797	1.795	1.793	1.79	1.787	1.781	1.773	1.762
	Far	1.801	1.801	1.802	1.803	1.804	1.806	1.809	1.813	1.819	1.827	1.840
2 m	Near	1.998	1.998	1.997	1.996	1.994	1.992	1.988	1.983	1.976	1.967	1.953
	Far	2.001	2.002	2.003	2.004	2.006	2.008	2.012	2.016	2.024	2.034	2.049
2.25 m	Near	2.248	2.247	2.246	2.245	2.242	2.239	2.235	2.229	2.219	2.208	2.19
	Far	2.251	2.252	2.253	2.255	2.257	2.260	2.265	2.271	2.281	2.293	2.313
2.5 m	Near	2.498	2.497	2.495	2.493	2.49	2.487	2.481	2.474	2.462	2.448	2.426
	Far	2.502	2.503	2.504	2.506	2.509	2.513	2.519	2.526	2.539	2.554	2.579
2.75 m	Near	2.747	2.746	2.744	2.742	2.738	2.734	2.727	2.718	2.704	2.687	2.66
	Far	2.752	2.754	2.755	2.758	2.761	2.766	2.773	2.782	2.797	2.815	2.846
3 m	Near	2.997	2.995	2.993	2.99	2.986	2.981	2.972	2.962	2.945	2.925	2.893
	Far	3.003	3.004	3.007	3.009	3.014	3.019	3.028	3.038	3.056	3.078	3.115
3.5 m	Near	3.495	3.493	3.491	3.487	3.481	3.474	3.462	3.448	3.425	3.398	3.354
	Far	3.504	3.506	3.509	3.513	3.519	3.526	3.538	3.553	3.577	3.608	3.659
4 m	Near	3.994	3.991	3.988	3.983	3.975	3.965	3.951	3.933	3.903	3.867	3.81
	Far	4.006	4.008	4.012	4.017	4.025	4.035	4.050	4.069	4.102	4.142	4.210
4.5 m	Near	4.492	4.489	4.484	4.478	4.469	4.456	4.438	4.415	4.377	4.332	4.26
	Far	4.507	4.511	4.515	4.522	4.531	4.544	4.564	4.588	4.630	4.681	4.8
5 m	Near	4.99	4.986	4.98	4.973	4.961	4.946	4.923	4.894	4.848	4.793	4.71
	Far	5.009	5.013	5.019	5.027	5.039	5.055	5.079	5.110	5.161	5.225	5.3
6 m	Near	5.986	5.98	5.972	5.961	5.944	5.922	5.889	5.848	5.782	5.7	5.58
	Far	6.014	6.019	6.028	6.039	6.057	6.080	6.115	6.16	6.235	6.3	6.5
8 m	Near	7.975	7.965	7.95	7.93	7.9	7.861	7.803	7.73	7.62	7.48	7.27
	Far	8.025	8.035	8.050	8.071	8.102	8.144	8.207	8.3	8.4	8.6	8.9
10 m	Near	9.961	9.945	9.921	9.89	9.844	9.783	9.69	9.58	9.4	9.2	8.88
	Far	10.03	10.05	10.07	10.11	10.16	10.22	10.3	10.5	10.7	11	11.5
20 m	Near	19.84	19.78	19.69	19.56	19.38	19.15	18.8	18.39	17.7	17	15.9
	Far	20.16	20.22	20.3	20.5	20.7	20.9	21.4	21.9	22.9	24.2	26.8

DEPTH OF FIELD
Metric

400mm

Circle of Confusion	Aperture										
0.05mm				1.4	2	2.8	4	5.6	8	11	16
0.037mm			1.4	2	2.8	4	5.6	8	11	16	22
0.025mm		1.4	2	2.8	4	5.6	8	11	16	22	32
0.017mm	1.4	2	2.8	4	5.6	8	11	16	22	32	
0.012mm	2	2.8	4	5.6	8	11	16	22	32		
Hyperfocal dist'	6400m	4571m	3200m	2286m	1600m	1143m	800m	582m	400m	291m	200m

Focus distance		Extreme distance in acceptable focus, meters										
1 m	Near	1	1	1	1	0.999	0.999	0.999	0.998	0.998	0.997	0.996
	Far	1.000	1.000	1.000	1.000	1.000	1.000	1.001	1.001	1.002	1.003	1.004
1.2 m	Near	1.2	1.2	1.2	1.199	1.199	1.199	1.198	1.198	1.197	1.195	1.193
	Far	1.200	1.200	1.200	1.200	1.200	1.201	1.201	1.202	1.203	1.204	1.206
1.4 m	Near	1.4	1.4	1.399	1.399	1.399	1.398	1.398	1.397	1.395	1.394	1.391
	Far	1.400	1.400	1.400	1.400	1.401	1.401	1.402	1.403	1.404	1.406	1.409
1.6 m	Near	1.6	1.599	1.599	1.599	1.598	1.598	1.597	1.596	1.594	1.592	1.588
	Far	1.600	1.600	1.600	1.601	1.601	1.602	1.603	1.604	1.606	1.608	1.612
1.8 m	Near	1.8	1.799	1.799	1.799	1.798	1.797	1.796	1.795	1.792	1.79	1.785
	Far	1.800	1.800	1.801	1.801	1.801	1.802	1.803	1.805	1.807	1.810	1.815
2 m	Near	1.999	1.999	1.999	1.998	1.998	1.997	1.995	1.993	1.991	1.987	1.981
	Far	2.000	2.000	2.001	2.001	2.002	2.003	2.004	2.006	2.009	2.013	2.019
2.25 m	Near	2.249	2.249	2.248	2.248	2.247	2.246	2.244	2.242	2.238	2.233	2.226
	Far	2.250	2.251	2.251	2.252	2.253	2.254	2.256	2.258	2.262	2.266	2.274
2.5 m	Near	2.499	2.499	2.498	2.497	2.496	2.495	2.493	2.49	2.485	2.48	2.47
	Far	2.500	2.501	2.501	2.502	2.503	2.505	2.507	2.510	2.515	2.520	2.530
2.75 m	Near	2.749	2.748	2.748	2.747	2.745	2.744	2.741	2.738	2.732	2.725	2.714
	Far	2.751	2.751	2.752	2.753	2.754	2.756	2.759	2.762	2.768	2.775	2.786
3 m	Near	2.999	2.998	2.997	2.996	2.995	2.992	2.989	2.985	2.978	2.97	2.957
	Far	3.001	3.001	3.002	3.003	3.005	3.007	3.010	3.015	3.021	3.030	3.044
3.5 m	Near	3.498	3.497	3.496	3.495	3.493	3.49	3.485	3.48	3.47	3.46	3.441
	Far	3.501	3.502	3.503	3.505	3.507	3.510	3.514	3.520	3.53	3.541	3.560
4 m	Near	3.998	3.997	3.995	3.993	3.99	3.986	3.981	3.973	3.961	3.947	3.923
	Far	4.002	4.003	4.004	4.006	4.009	4.013	4.019	4.027	4.039	4.054	4.079
4.5 m	Near	4.497	4.496	4.494	4.491	4.488	4.483	4.475	4.466	4.451	4.433	4.403
	Far	4.503	4.504	4.506	4.508	4.512	4.517	4.524	4.534	4.550	4.569	4.601
5 m	Near	4.996	4.995	4.992	4.989	4.985	4.979	4.97	4.958	4.939	4.917	4.88
	Far	5.003	5.005	5.007	5.010	5.015	5.021	5.030	5.042	5.062	5.085	5.125
6 m	Near	5.994	5.992	5.989	5.985	5.978	5.969	5.956	5.94	5.913	5.881	5.828
	Far	6.005	6.007	6.011	6.015	6.022	6.031	6.044	6.061	6.089	6.124	6.182
8 m	Near	7.99	7.986	7.98	7.972	7.961	7.945	7.922	7.893	7.845	7.789	7.7
	Far	8.009	8.013	8.019	8.027	8.039	8.055	8.079	8.110	8.161	8.223	8.3
10 m	Near	9.985	9.978	9.969	9.957	9.939	9.914	9.878	9.833	9.759	9.67	9.53
	Far	10.01	10.02	10.03	10.04	10.06	10.08	10.12	10.17	10.25	10.4	10.5
20 m	Near	19.93	19.91	19.87	19.82	19.75	19.66	19.51	19.34	19.05	18.72	18.19
	Far	20.06	20.08	20.12	20.17	20.25	20.4	20.5	20.7	21	21.5	22.2

14 LIGHT AND COLOR

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Light is the bread and butter of our craft. We study it, we use it, we earn our livings by it. It is, therefore, worth our while to know a little of what it actually is and how it behaves.

14.1 THE ELECTROMAGNETIC SPECTRUM

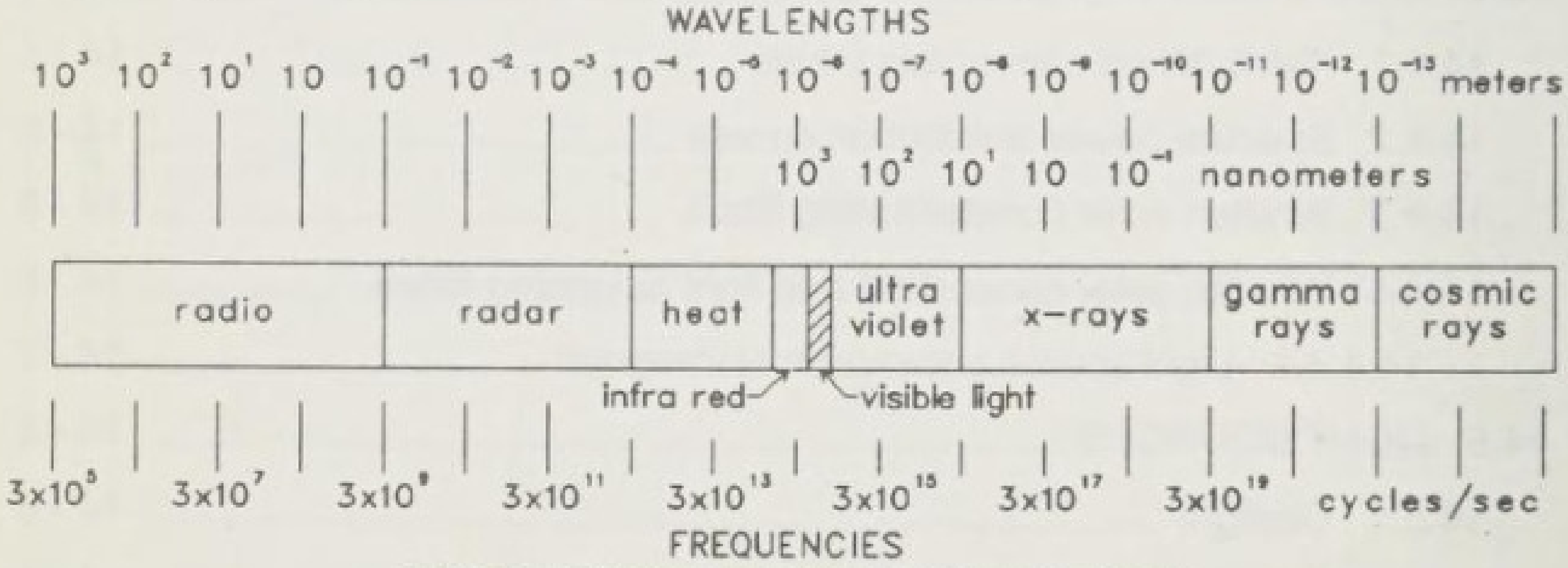
Throw a pebble into a shallow pool of still water and a wave or ripple will be seen to emanate from the point of contact. Leaves floating on the surface will bob up and down but not move forward. From this we may deduce that the water is not moved away from the source of radiation but vibrates. As the circle of vibration moves further away from its point of origin and its energy is spread over an ever increasing circle, its strength (amplitude) is diminished but its speed (frequency) remains constant.

If instead of a single pebble a plunger is used, moving up and down at regular intervals of time, we will have a continuing series of waves all at the same distance apart (wave length) all across the pool. If, instead of water, we had thick oil the ripples would move more slowly while still remaining the same distance apart. If such oil were blobs in the water in the shape of a lens or prism, where the oil was thickest the ripples would be most delayed. Where the ripples meet the oil at an angle the progressive slowing down would change their direction, effectively focusing, dispersing or bending the waves to an extent depending upon the thickness of the oil and the angles of incidence.

A smooth wall would reflect the ripples at the same angle of incidence as it was struck while a rough series of rocks would stop the movement by dispersing it in all directions.

Light waves, together with radio, heat, and X-rays, etc., are electromagnetic waves which conform to the same principles as the pebble in the pond, the wavelength of visible light being about 1/50,000 in. (0.0005mm).

The spectrum of electromagnetic radiation covers wavelengths from millions of meters to millionths of meters and includes bands which we use to carry radio signals, to heat ourselves by, to see by and to see through ourselves by.


WAVELENGTHS
10^3 10^2 10^1 10 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12} 10^{-13} meters
10^3 10^2 10^1 10 10^{-1} nanometers
radio
radar
heat
ultra violet
x-rays
gamma rays
cosmic rays
infra red
visible light
$3x10^5$ $3x10^7$ $3x10^9$ $3x10^{11}$ $3x10^{13}$ $3x10^{15}$ $3x10^{17}$ $3x10^{19}$ cycles/sec
FREQUENCIES

THE ELECTROMAGNETIC SPECTRUM

Within the visible range, from 400 to 760nm approximately, white light is made up of all colors in the spectrum, each having its own wavelength:

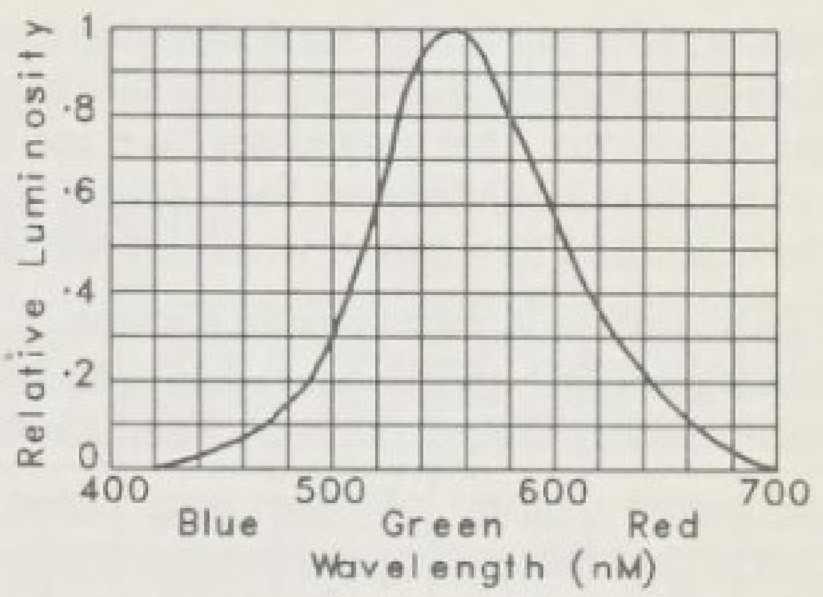
Wavelength (Nanometers)	Color
400	Violet
475	Blue-purple
484	Blue
492	Blue-green
508	Green
565	Green-yellow
578	Yellow
590	Orange
615	Orange-red
700	Red

(1 nanometer = 1 millimicron = 0.000001mm = m^{-9}

THE WAVELENGTHS OF INDIVIDUAL COLORS WITHIN THE VISIBLE SPECTRUM

14.2 THE PHOTOPIC CURVE

Within the visible range, the response of the human eye is not uniform but falls off either side of a point of maximum sensitivity. For most people this is approximately 555 nm, a greenish yellow color. The response curve varies slightly between individuals, but to avoid confusion in measurement, there is an agreed curve for a standard eye at normal levels of stimulation. This curve is known as the PHOTOPIC CURVE.



SPECTRAL RESPONSE OF THE AVERAGE EYE

It is said that more than 10% of the population suffer from some sort of color vision deficiency or 'Color Blindness'. In most cases this consists of seeing some colors as gray and in other cases there is an imbalance of color hue or of the brightness of a particular color.

The measurement of light is concerned with the measurement of radiation 'weighted' to account for the subjective effects on an average observer. Luminous Flux (Lumens) = Radiant Power (Watts) × Photopic Curve.

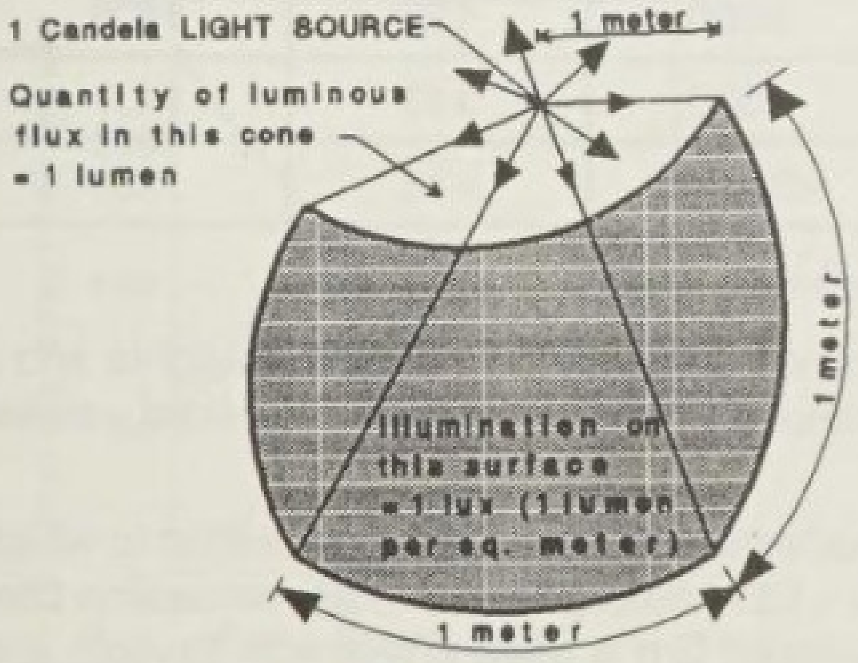
14.3 MEASURING THE QUANTITY OF LIGHT

The intensity of LIGHT is measured by comparing it to a standard light source, the original source being that of a standard candle. One Candela approximately equals the light from one candle.

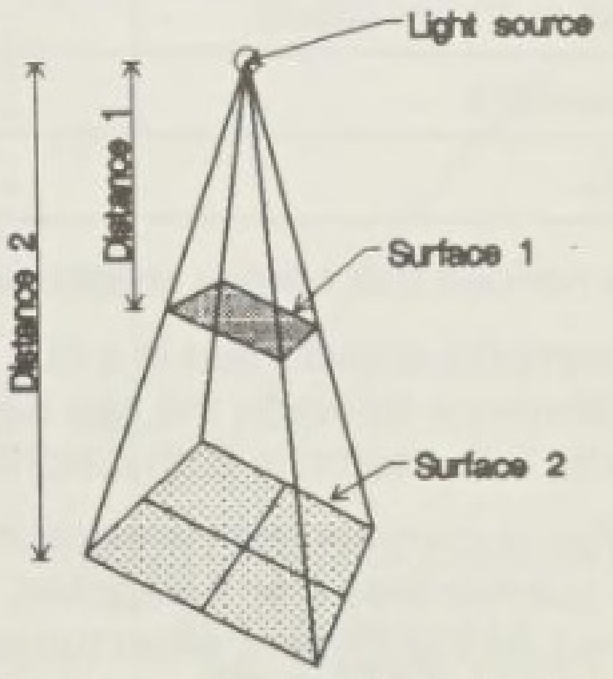
The LUMINOUS FLUX emanating from a light source is radiant energy weighted by the photopic curve and is measured in Lumens.

ILLUMINATION is Luminous Flux incident onto a surface and is measured in Lumens/m^2 and known as Lux.

LUMINANCE is the measure of reflected light from a surface.


1 Candela LIGHT SOURCE
1 meter
Quantity of luminous flux in this cone = 1 lumen
Illumination on this surface = 1 lux (1 lumen per sq. meter)
1 meter
1 meter

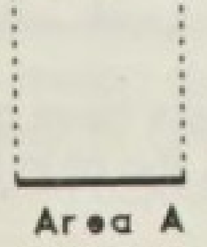
1 LUMEN OF LIGHT FALLING ON A SPHERICAL SURFACE
1 METER × 1 METER = 1 LUX.



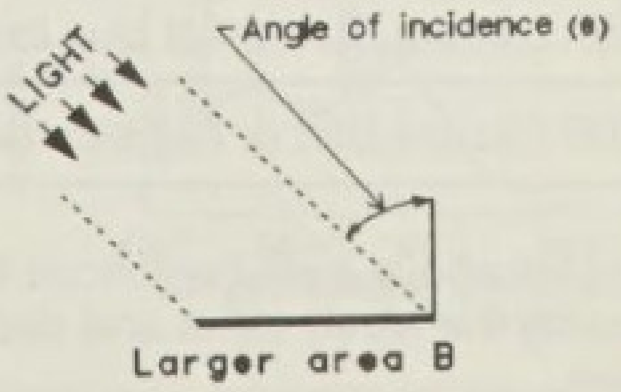
IF THE DISTANCE IS DOUBLED THE ILLUMINATION WILL BE QUARTERED, i.e. 1 LUMEN PER 4 SQ. METERS = 0.25 LUX.

The fact that 'The Intensity of Light Diminishes by the Square of the Distance' is known as the 'Inverse Square Law'.

Light incident at an angle to a surface results in a reduced illumination proportional to the cosine of the angle of incidence. This law is know as the Cosine Law of Illumination. (See Section 14.5.2.)



LIGHT FALLING PERPENDICULAR TO A SURFACE ILLUMINATES AREA A.



LIGHT FALLING AT AN ANGLE TO A SURFACE ILLUMINATES AREA B.

14.4 MEASURING THE QUALITY OF LIGHT

In addition to the amount of light available for photography, the quality, i.e. the color of a light source determined by the distribution of radiant flux within the visible spectrum, must also be measured. This may either be done by comparing the color of the source to the color of an ideal incandescent body (black body) heated to a particular temperature or it may be illustrated by a graph which compares relative energy against wave length.

Color temperature is measured in Kelvins (K, often written as °K). 'Mean Noon Sunlight in Washington DC' (5500 K) is taken to be the average sunlight color temperature, tungsten filament lamps, normally used for motion picture lighting are 3200 K.

An alternative method of measuring color temperature is the MIRED value, 'Micro Reciprocal degrees', which are Kelvins divided into 1,000,000. They are a more workable measure of color temperature because, unlike Kelvins, they provide approximately proportional differences between color temperature ratings of widely differing light sources. This makes it very much easier to calculate the effect of any color correction.

$$Mireds = \frac{1,000,000}{Kelvins} \qquad Decamireds = \frac{100,000}{Kelvins}$$

Typical Mired and Decamired values are:

Light source	Kelvin	Mired	Decamired
Standard candle	1930	518	51.8
Dawn sunlight	2000	500	50
Domestic electric light bulb	2900	345	34.5
Tungsten artificial light	3200	313	31.3
Photoflood artificial light	3400	294	29.4
One hour after sunrise	3500	286	28.6
Early morning and late afternoon sunlight	4500	233	23.3
Photographic daylight	5500	182	18.2
Metal Halide (HMI, etc.) lighting	5500	182	18.2
Average daylight (sun + sky combined)	6500	164	16.4
Average summer shade	8000	125	12.5
Hazy sunlight	9000	111	11.1
Blue sky	<30,000	>33	>3

It will be noticed that Mireds reduce as Kelvins rise.

In the examples above there is a 200 K difference between the two artificial lights and a 600 K difference between the two daylights and yet the difference in the Mired values, 18 Mireds, is the same in both instances.

To change or correct color temperature it is necessary to introduce a color filter to which a Mired number may also be applied. Thus a +131 Mired (Wratten 85B) correction filter is required on the camera when tungsten balanced film is used in average daylight and an 80A filter is required when daylight balanced film is used to photograph by tungsten light.

Conversely, an orange filter may be used on a daylight colored lamp (HMI etc.) to balance it for tungsten film or a blue filter on a tungsten lamp to balance it to daylight.

Filter	Mired	Decamired
Wratten 85B camera filter or CTO orange lamp filter	+131	+13.1
Wratten 85 camera filter or half CTO orange lamp filter	+112	+11.2
Wratten 80A camera filter or full blue lamp filter	-132	-3.2
Wratten 80B camera filter or half blue lamp filter	-66	-6.6

In the examples above it will be noticed that the amber colored filters have plus values, thus increasing the Mired value and decreasing the Kelvins, and the blue filters have minus values.

14.4.1 Kelvin/Mired conversion tables

To use, make up the number to be converted by adding the unit at the side of a line to the unit at the head of a column. The conversion number is where line and column meet. i.e. 3200K is 312 Mireds.

KELVIN TO MIREDS

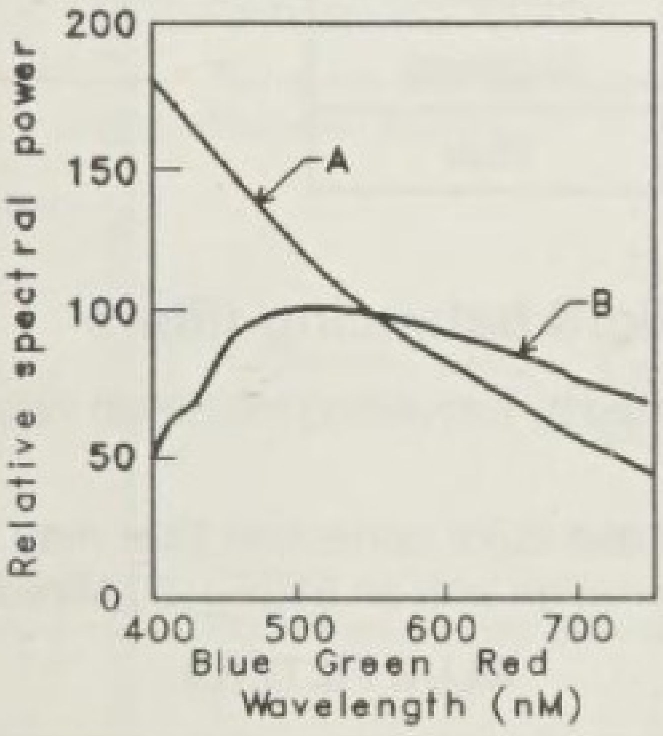
Kelvin	000	100	200	300	400	500	600	700	800	900
2000	500	476	455	435	417	400	385	370	357	345
3000	333	323	312	303	294	286	278	270	263	256
4000	250	244	238	233	227	222	217	213	208	204
5000	200	196	192	189	185	182	179	175	172	169
6000	167	164	161	159	156	154	152	149	147	145
7000	143	140	139	137	135	133	132	130	128	126
8000	125	123	122	120	119	118	116	115	114	112

MIREDS TO KELVIN

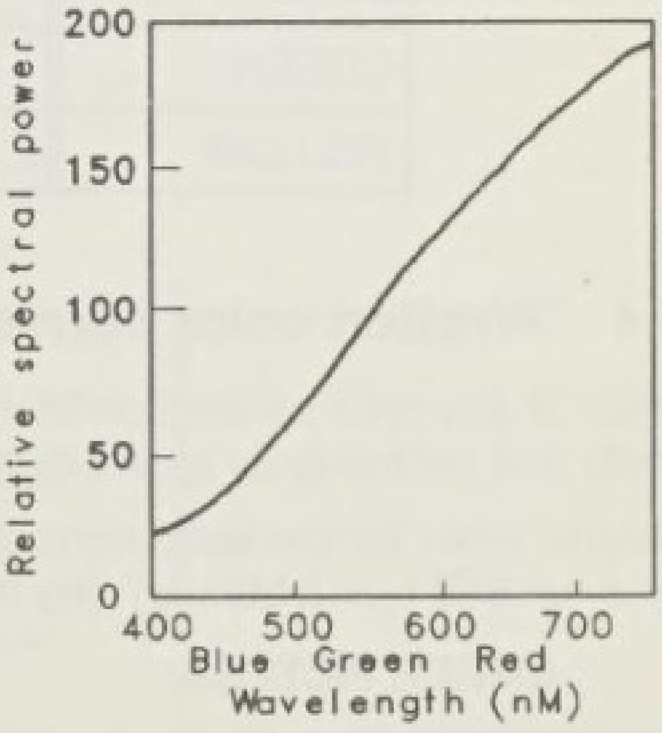
Mireds	00	10	20	30	40	50	60	70	80	90
100	10,000	9090	8333	7692	7143	6667	6250	5882	5556	5263
200	5,000	4762	4546	4347	4167	4000	3846	3708	3571	3448
300	3,333	3226	3125	3030	2941	2857	2778	2703	2631	2568

14.4.2 Spectral power distribution curves

Daylight and tungsten and carbon arc artificial light sources of illumination emit a continuous spectrum of light but differ in their color balance according to their 'color temperature'. A light of low color temperature is quite red whereas a light of high color temperature is quite blue.

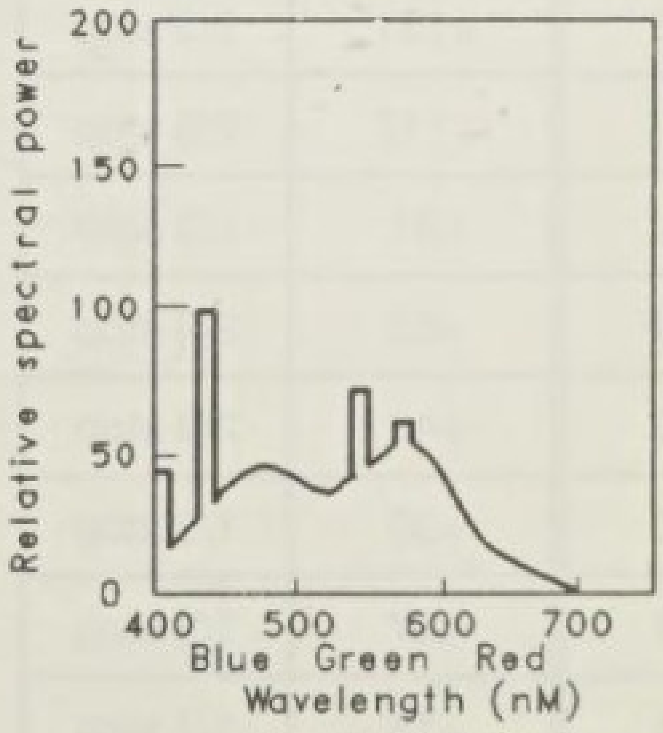


SPECTRAL POWER DISTRIBUTION CURVES OF SUNLIGHT: A. BLUE SKY, B. MEAN NOON SUNLIGHT



SPECTRAL POWER DISTRIBUTION CURVE OF TUNGSTEN LIGHT

Fluorescent and Metal Halide (HMI, etc.) type light sources emit a discontinuous spectrum of light with extremely bright 'spikes' in some narrow bands of the spectrum. By the use of rare earths and other devices they are usually balanced out to emit a light the overall spectrum of which, to the human eye, approximates to either daylight or tungsten light but which to color filmstock (or to a color temperature meter) may not necessarily be so, leading to uneven exposure of discrete colored objects.



SPECTRAL POWER DISTRIBUTION CURVE OF A TYPICAL 'DAYLIGHT' TYPE FLUORESCENT LIGHT. Note spikes in the blue and green wavebands.

14.4.3 Wratten color compensating filters

Overall changes in the exposure balance of color filmstock, as it affects each of the three layers, may be achieved by the use of color compensating filters available in cyan, magenta, yellow, red, green and blue in densities of 0.05, 0.10, 0.20, 0.30, 0.40 and 0.50. These filters are principally used in film laboratories and for critical special effects work.

COLOR COMPENSATING FILTERS

Peak density	0.05	0.10	0.20	0.30	0.40	0.50
Cyan Exp. incr. stops	CC05C 1/3	CC10C 1/3	CC20C 1/3	CC30C 2/3	CC40C 2/3	CC50C 2/3
Magenta Exp. incr. stops	CC05M 1/3	CC10M 1/3	CC20M 1/3	CC30M 2/3	CC40M 2/3	CC50M 2/3
Yellow Exp. incr. stops	CC05Y 1/3	CC10Y 1/3	CC20Y 1/3	CC30Y 1/3	CC40Y 2/3	CC50Y
Red Exp. incr. stops	CC05R 1/3	CC10R 1/3	CC20R 1/3	CC30R 2/3	CC40R 2/3	CC50R 1
Green Exp. incr. stops	CC05G 1/3	CC10G 1/3	CC20G 1/3	CC30G 2/3	CC40G 2/3	CC50G 1
Blue Exp. incr. stops	CC05B 1/3	CC10B 1/3	CC20B 2/3	CC30B 2/3	CC40B 1	CC50B 1 1/3

To lighten a color use a filter of similar color.

To darken a color use a filter of complementary (opposite) color.

COLOR	FILTER TO LIGHTEN	FILTER TO DARKEN
RED	Red	Cyan
MAGENTA	Magenta	Green
BLUE	Blue	Yellow
CYAN	Cyan	Red
GREEN	Green	Magenta
YELLOW	Yellow	Blue

14.4.4 Wratten color conversion and light balancing filters

The effect of any color conversion filter may be calculated by converting the Kelvin values to Mireds and selecting an appropriate filter.

For greater color temperature correction more than one color correction filter may be used, i.e. an 85B (+312 Mireds) may be used in combination with an 81EF (+53 Mireds).

AMBER FILTERS

Filter	Mired shift	Exposure increase
85B	+131	2/3 stop
85	+112	2/3 stop
85C	+81	1/3 stop
81EF	+53	2/3 stop
81D	+42	2/3 stop
81C	+35	1/3 stop
81B	+27	1/3 stop
81A	+18	1/3 stop

BLUE FILTERS

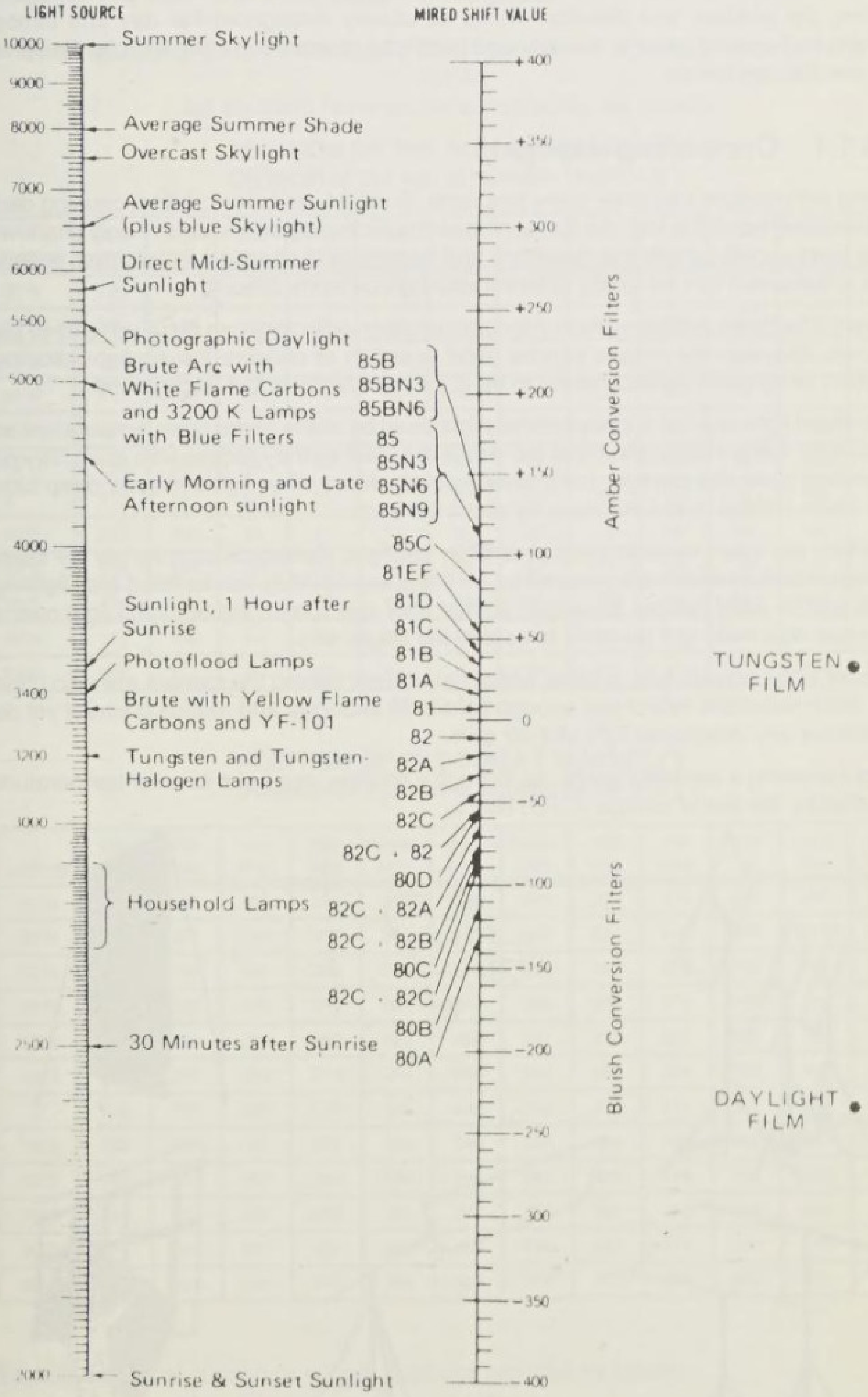
Filter	Mired shift	Exposure increase
80A	-131	2 stops
80B	-112	1 2/3 stops
80C	-81	1 stop
80D	-56	1/3 stop
82C	-45	2/3 stop
82B	-32	2/3 stop
82A	- 18	1/3 stop

14.4.4.1 Light source conversion Nomogram

The following Nomogram is an easy way to check which color correction or light balancing filter should ideally be used for a given type of filmstock in a particular lighting color temperature situation.

To use, place a straight edge on the Nomogram joining the appropriate point on the color temperature scale to the dot by the type of filmstock to be used. Where the line crosses the central vertical scale indicates the filter required and the Mired shift number.

NOMOGRAM FOR WRATTEN COLOR CONVERSION FILTERS



14.5 LIGHT SOURCES

Beyond the point where there is sufficient light for exposure purposes, light and the control of it provides a means for imparting a mood and an atmosphere to the entire image and ultimately to interpreting the script. Light is used for modelling, for enhancing detail and for filling shadows. Equally important to the art of lighting is the use of shade and shadow.

14.5.1 Daylight

Daylight is the most commonly used form of film lighting. While one can always be sure that it will become available on time, the time is dependent upon date and terrestrial location, the position and direction varies constantly throughout the day and almost nowhere in the world can the quantity and quality be guaranteed to be exactly the same as it was the day before.

14.5.1.1 Controlling daylight

Lighting with sunlight can pose many problems. Sunlight can be too strong, causing dark shadows where detail is lost, the sun can be too high causing artists to have only shadows where eyes should be and the directions and intensities of shadows in adjoining scenes within a sequence can be totally different making continuity difficult.

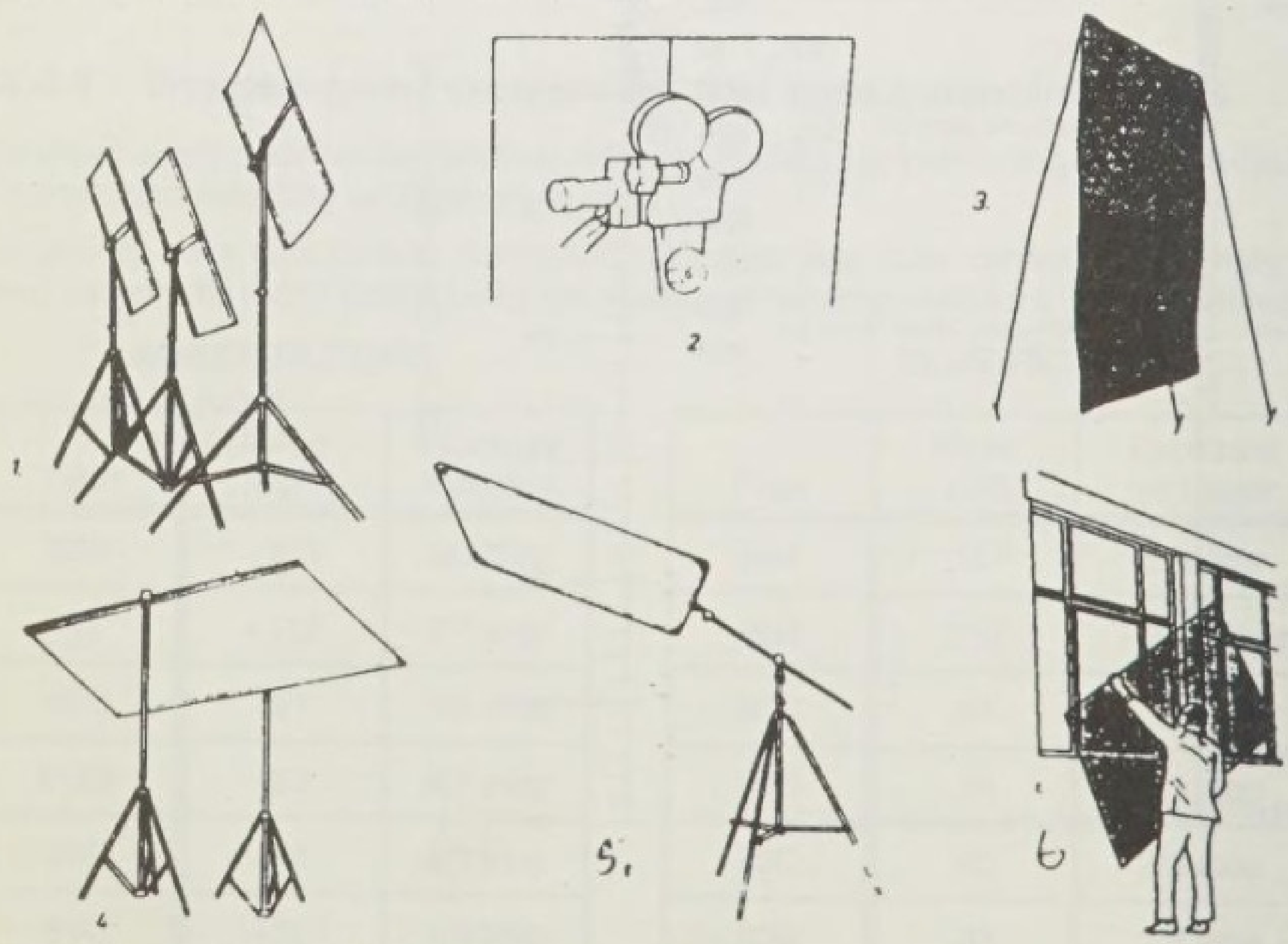
To overcome these problems high intensity lamps or reflectors can be used to fill-in the shadows. Alternatively, means can be used to soften or obscure the sunlight allowing important foreground subject matter to be lit independently of the background.

Any artificial light used to supplement daylight must be of the same color temperature as the daylight. Metal Halide and brute arc lamps are ideal as they require little or no filtering (depending upon the daylight color temperature). Most other lights require deep blue filters which reduce their luminosity by about 2/3 stop.

Reflectors are often used to control or fill-in sunlight. Reflectors can simply be silver material on boards which are propped up on the ground or they can be fitted onto lighting stands and be semi-flexible (bowable) so that they can spread the reflected light over a wide area, also making it possible to control the brightness.

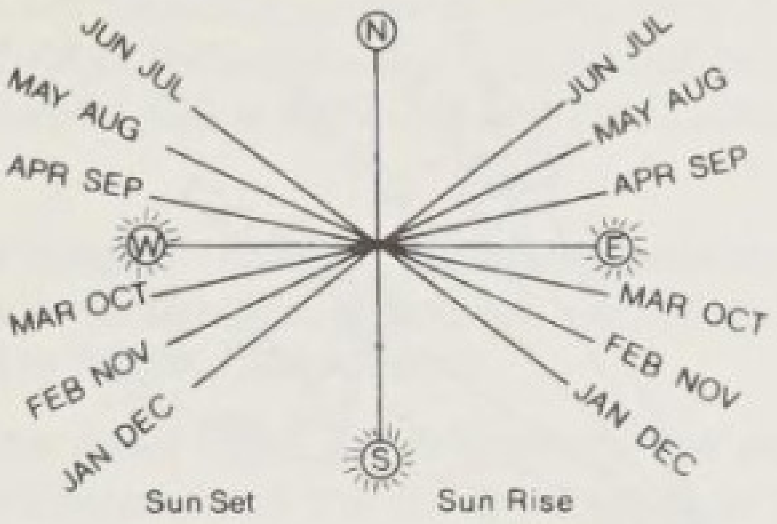
Sheets of white polystyrene or other white material set behind the camera are also often used. Such reflectors reflect just enough light to fill shadows and reduce contrast yet do not produce any directional light of their own.

Daylight entering a confined space, as through a window, can have its color temperature controlled by the use of orange (CTO) filters.



MEANS TO CONTROL DIRECT SUNLIGHT: 1. 'Bowable' reflectors, 2. Sheets of white polystyrene behind the camera, 3. Blackout, 4. Large net or 'butterfly', 5, Silk, scrim or other light softening material, 6. Large orange colored filters placed over windows when shooting inside by artificial light.

14.5.1.2 Sunrise/sunset positions



AVERAGE MONTHLY POSITIONS OF THE SUN AT SUNRISE AND SUNSET (50°N),
for southern hemisphere transpose by six months.

POSITION OF THE SUN AT SUNRISE (°)
(Azimuth of the sun at sunrise, North = 0°)

Latitude	mid Jan.	mid Feb.	mid Mar.	mid April	mid May	mid June	mid July	mid Aug.	mid Sept.	mid Oct.	mid Nov.	mid Dec.
60°N	135	115	94	70	49	35	39	57	81	105	127	141
50°N	123	110	93	75	59	51	53	65	83	102	118	127
40°N	118	107	93	77	65	58	60	70	84	100	114	121
30°N	114	105	93	79	68	62	64	72	85	99	111	117
20°N	113	104	93	80	70	65	66	74	86	98	109	115
10°N	112	103	93	80	71	66	67	75	86	98	109	114
0°	111	103	93	81	71	67	68	75	86	98	109	113
10°S	112	103	93	81	71	66	68	75	86	98	109	114
20°S	113	104	93	81	69	65	67	74	86	99	110	115
30°S	116	106	94	80	66	63	65	73	86	100	112	118
40°S	119	108	94	79	62	60	61	71	86	101	115	122
50°S	126	112	95	77	62	53	55	67	85	104	121	130

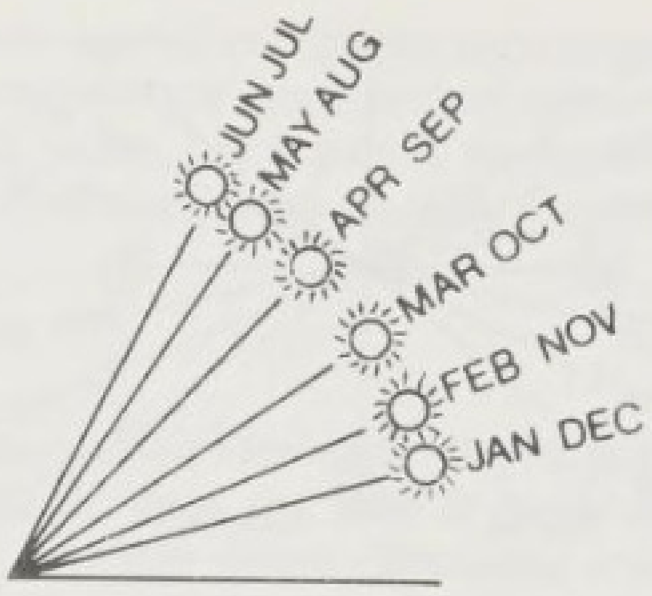
POSITION OF THE SUN AT SUNSET (°)
(Azimuth of the sun at sunset, North = 0°)

Latitude	mid Jan.	mid Feb.	mid Mar.	mid April	mid May	mid June	mid July	mid Aug.	mid Sept.	mid Oct.	mid Nov.	mid Dec.
60°N	225	245	266	290	311	325	321	302	279	255	232	219
50°N	237	251	267	286	301	310	307	294	277	258	241	233
40°N	242	254	267	283	295	302	300	290	275	260	246	239
30°N	246	255	268	281	292	298	296	288	275	261	249	243
20°N	248	256	268	280	290	295	294	286	274	261	250	245
10°N	248	257	268	279	289	294	293	285	274	262	251	246
0°	249	257	268	279	289	293	292	285	274	262	251	246
10°S	248	257	267	279	289	294	292	284	273	261	251	246
20°S	247	256	267	280	269	295	293	285	274	261	250	245
30°S	245	254	267	280	291	297	295	287	274	260	248	242
40°S	241	252	267	281	294	300	299	289	274	258	245	238
50°S	234	249	266	283	299	307	305	292	275	256	239	230

To calculate local sunrise or sunset positions proceed as follows:

1. Note the local latitude (from a map, etc.).
2. Select the nearest sunrise or sunset position from the tables above, interpolating the date and latitude as necessary for greater accuracy.
3. If using a magnetic compass a correction must be made to allow for the local Magnetic Variation. In the western hemisphere add westerly variation and subtract easterly variation from the True heading to find the magnetic heading. In the eastern hemisphere add easterly variation and subtract westerly.

14.5.1.3 Maximum sun altitude



HIGHEST ALTITUDE OF THE SUN AT LOCAL MID-DAY (50°N),
for southern hemisphere transpose by six months.

MAXIMUM ALTITUDE OF THE SUN AT LOCAL MID-DAY

Latitude	mid Jan.	mid Feb.	mid Mar.	mid April	mid May	mid June	mid July	mid Aug.	mid Sept.	mid Oct.	mid Nov.	mid Dec.
60°N	9°S	17°S	26°S	40°S	49°S	53°S	51°S	44°S	33°S	21°S	12°S	7°S
50°N	19°S	27°S	36°S	50°S	59°S	63°S	61°S	54°S	43°S	31°S	22°S	17°S
40°N	29°S	37°S	46°S	60°S	69°S	73°S	71°S	64°S	53°S	41°S	32°S	27°S
30°N	39°S	47°S	56°S	70°S	79°S	83°S	81°S	74°S	63°S	51°S	42°S	37°S
20°N	49°S	57°S	66°S	80°S	89°S	87°S	89°S	84°S	73°S	61°S	52°S	47°S
10°N	59°S	67°S	76°S	90°	81°S	77°S	79°S	86°S	83°S	71°S	62°S	57°S
0°	69°S	77°S	86°S	80°N	71°S	67°S	69°S	76°S	87°S	81°S	72°S	67°S
10°S	79°N	87°N	84°N	70°N	61°N	57°N	59°N	66°N	77°N	89°N	82°N	77°N
20°S	89°N	83°N	74°N	60°N	51°N	47°N	49°N	56°N	67°N	79°N	88°N	87°N
30°S	81°N	73°N	64°N	50°N	41°N	37°N	39°N	46°N	57°N	69°N	78°N	83°N
40°S	71°N	63°N	54°N	40°N	31°N	27°N	29°N	36°N	47°N	59°N	68°N	73°N

14.5.1.4 Hours of daylight

HOURS OF DAYLIGHT (hrs)
(Sunrise to sunset time to the nearest 15 minutes)

Latitude	mid Jan.	mid Feb.	mid Mar.	mid April	mid May	mid June	mid July	mid Aug.	mid Sept.	mid Oct.	mid Nov.	mid Dec.
60°N	6 3/4	91/4	11 3/4	141/2	171/4	18 3/4	18	15 3/4	131/4	101/4	71/2	6
50°N	81/2	101/4	12	13 3/4	151/2	161/4	16	151/2	121/2	101/4	9	8
40°N	9 3/4	10 3/4	12	13 3/4	141/2	15	14 3/4	13 3/4	121/2	111/4	10	91/4
30°N	101/2	111/4	12	13	13 3/4	14	14	131/4	121/4	111/2	101/2	101/4
20°N	11	111/2	12	121/2	13	131/4	131/4	12 3/4	121/4	11 3/4	111/4	11
10°N	111/2	11 3/4	12	121/4	121/2	131/4	12 3/4	121/2	121/4	12	11 3/4	111/2
0°	12	12	12	12	12	12	12	12	12	12	12	12
10°S	12 3/4	121/2	121/4	12	11 3/4	111/2	111/2	11 3/4	12	12	121/2	12 3/4
20°S	131/4	12 3/4	121/4	11 3/4	111/4	11	11	111/2	12	121/2	13	131/4
30°S	14	131/4	121/4	111/2	101/2	101/4	101/2	111/4	12	13	13 3/4	14
40°S	14 3/4	13 3/4	121/2	111/4	10	91/4	9 3/4	10 3/4	12	131/4	141/2	15

14.5.2 Dawn and Dusk times

The few minutes of usable light before sunrise or after sunset are often known as the 'Magic Hour' or the 'Golden Minutes' and are much used by cinematographers either because of the wonderful soft, golden, quality the light has at that time or because there is still sufficient light to film by and yet practical lights (street lights, car headlights, window lights, etc.) all stand out as though it were night time.

For these reasons film making often has to be scheduled to take advantage of these times. In Astronomic Time Calculations this time is when the sun is 6° below the horizon and is known as 'Civil Twilight'. (Nautical Twilight is 12° and Astronomical Twilight 18°.)

14.5.3 Tungsten Halogen lighting

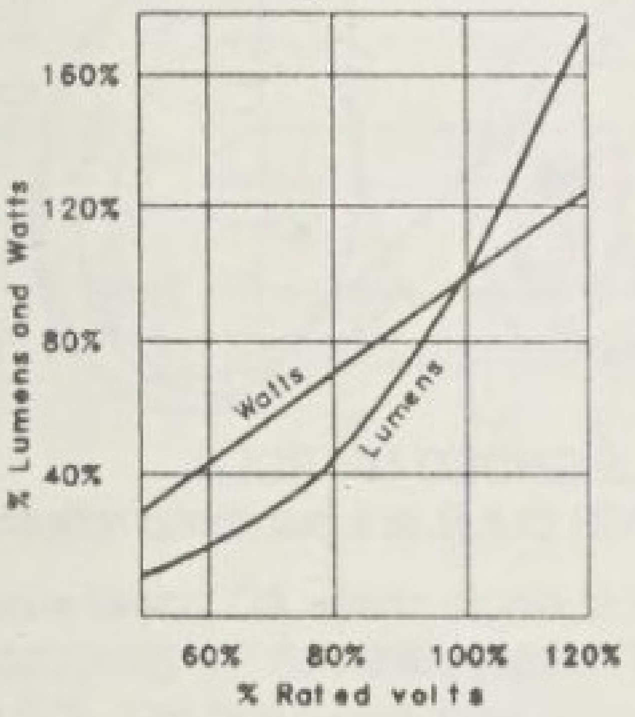
Tungsten Halogen bulbs are basically similar to those used for domestic purposes but operate at a very much higher temperature and in an atmosphere of halogen gasses. Their wattages range between 200 and 20,000 and they produce about 27 - 28 lumens per watt.

The color temperature of tungsten halogen photographic bulbs at their rated voltage is 3200K (312 Mireds). Photoflood bulbs, which are sometimes used in 'practical' light fittings, give a light which is 3400K (294 Mireds).

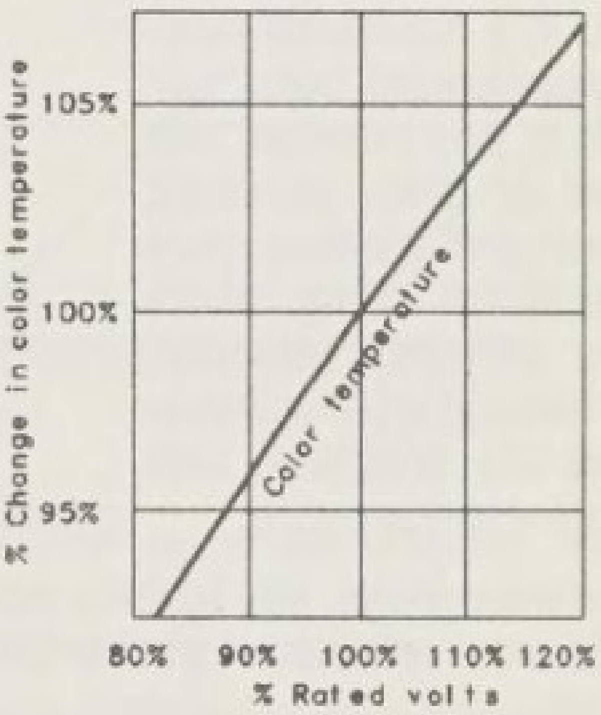
If the voltage is above the rated value the brightness, the color temperature and the lumens per watt will be increased and the life expectancy of the bulb will be reduced. There is no loss of efficiency with usage.

Bulbs which incorporate their own reflector and optical system give out relatively more usable light.

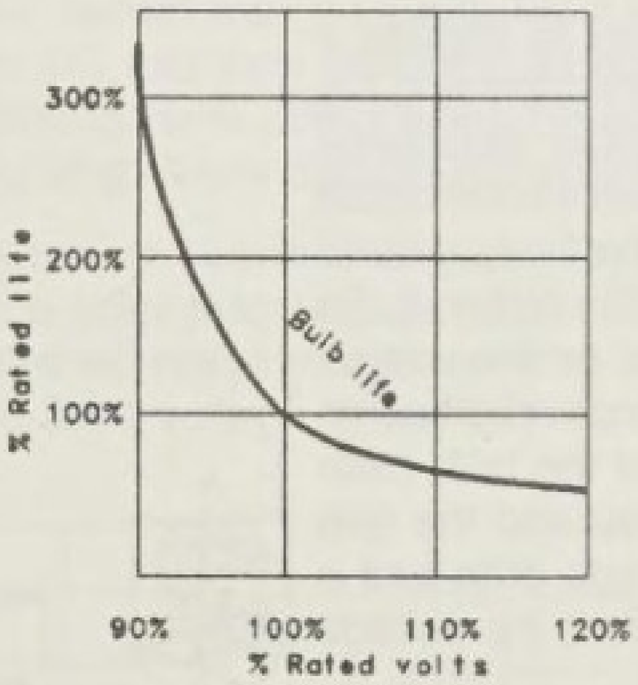
Because of the nature of the material of which they are made, tungsten-halogen lamps not incorporating a reflector and lens must never be touched with bare fingers. A piece of cloth or gloves must be used when fitting a new bulb. Handling will cause blackening and premature failure. Should an expensive bulb be accidentally handled the finger marks should immediately be washed off with white spirit or alcohol.



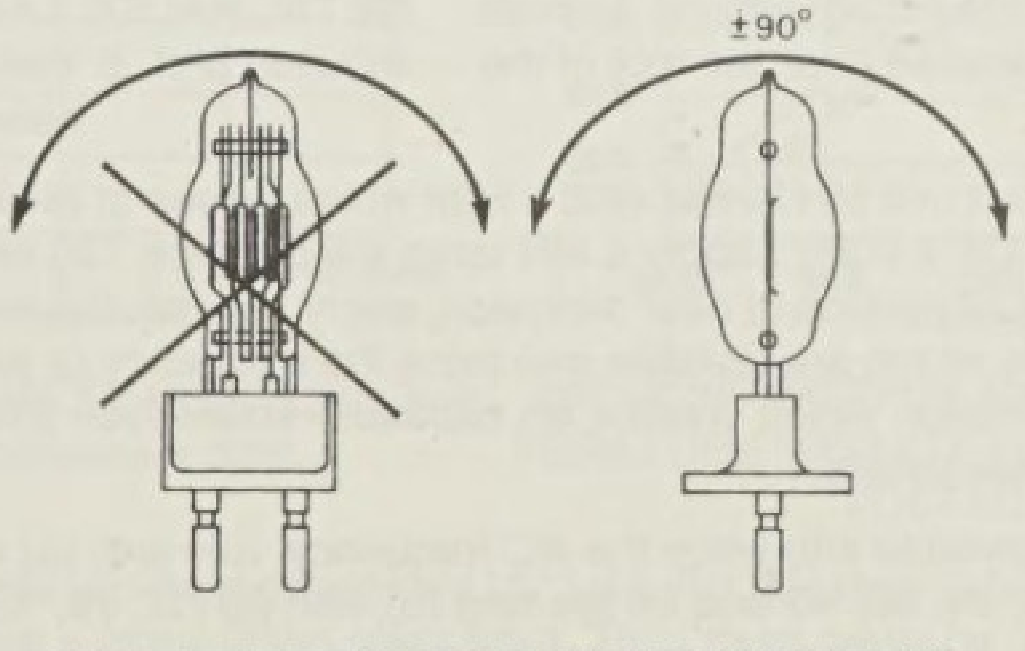
LIGHT OUTPUT AND WATTAGE VARIATION WITH APPLIED VOLTAGE



VARIATION IN COLOR TEMPERATURE WITH VOLTAGE



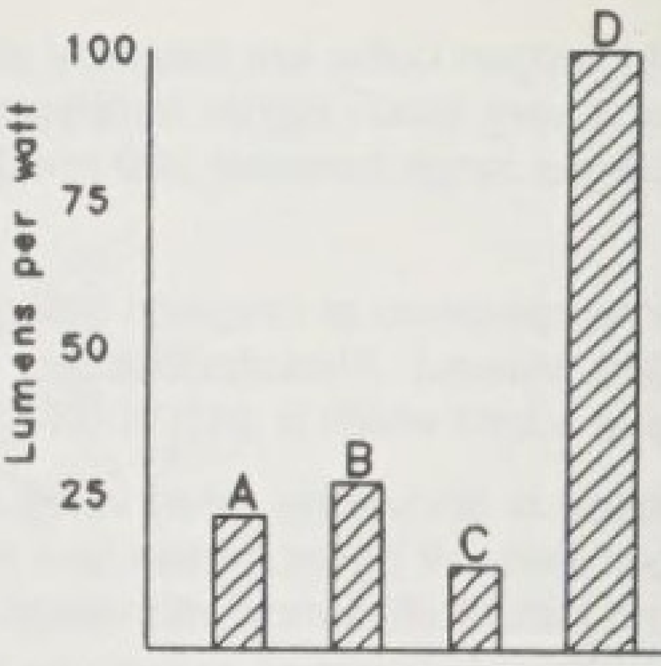
BULB LIFE VARIATION WITH VOLTAGE



BULBS MUST NOT BE TILTED SIDEWAYS

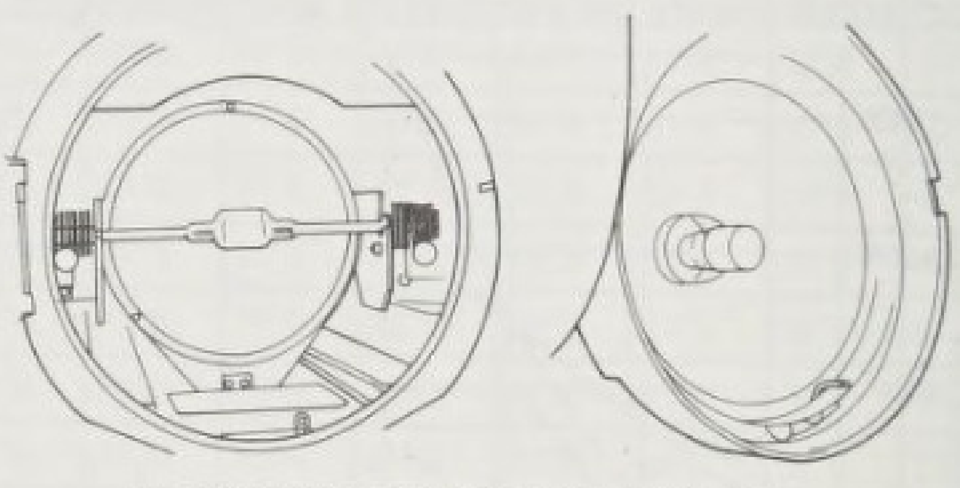
14.5.4 Metal Halide lighting

Metal Halide lamps (HMI etc.) are highly efficient enclosed mercury arc discharge lamps many of which produce in excess of 100 lumens per watt of electrical energy consumed. This is some three to four times greater than is possible with tungsten halogen lighting, even more if it is necessary to use blue filters with the tungsten lighting. This means when working on location that much more light can be operated off an available power source or, when sufficient local power is not available, a smaller alternator will be required. In addition, the power cables need only be a quarter the size and weight, making them easier to transport and carry.



COMPARATIVE LIGHTING EFFICIENCY: A. Carbon arc; B. Tungsten halogen; C. Tungsten halogen with a blue filter; D. Metal Halide (HMI etc.).

Most MH bulbs, especially those of higher wattage, are double-ended and must only be used in a horizontal position. Single ended bulbs can be used in any position, can be used in deep parabolic reflectors (and are thus more light-efficient), being more compact and heat efficient, can be used in smaller housings and are dimmable with stable color temperature,



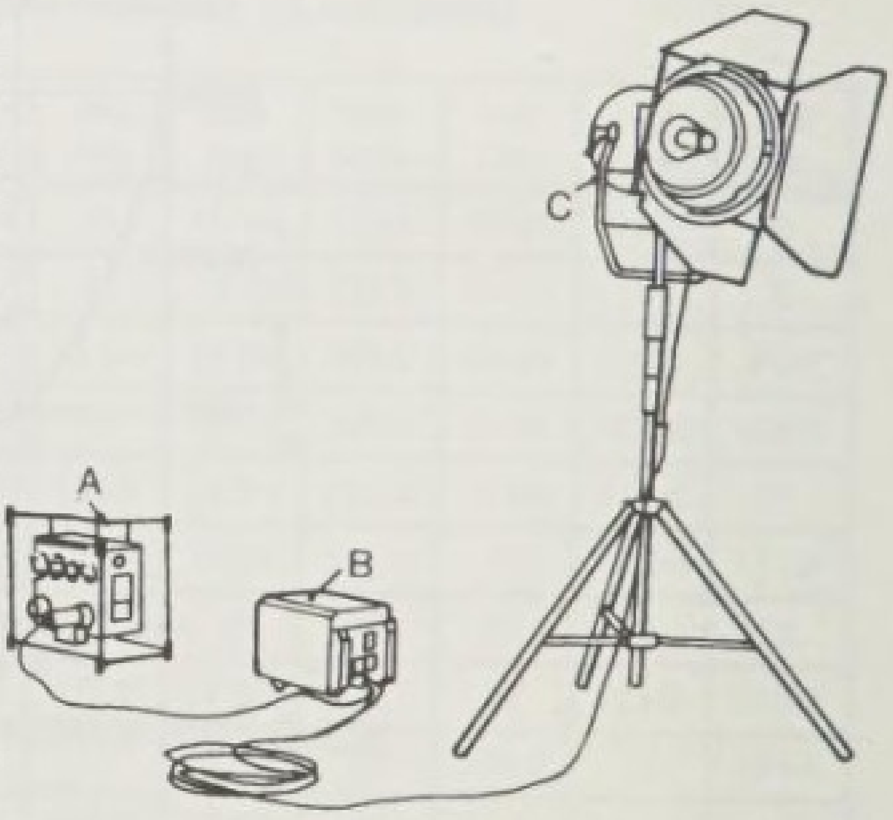
1. DOUBLE-ENDED MH BULB; 2. SINGLE-ENDED MH BULB in a parabolic reflector

With few exceptions, MH lighting requires a 50 or 60 Hz single phase AC power supply. Versions are available to operate off 120, 220 or 240 volt supplies.

200 watt MH lamps may be operated off a battery power supply and are a very convenient portable lighting unit. They give out almost as much light as a 1000 watt conventional lamp. Spotted down, they can even be used as a fill light when shooting exterior close-ups.

With MH lamps it is necessary to impose a ballast between the AC power supply and the bulb to: 1, Provide an electrical resistance when the arc is struck, to prevent a short circuit across the supply, and to effectively extend the life of the electrodes and the bulbs; 2, To smooth out small variations in the mains supply; 3, To keep the volts/amps relationship constant throughout the life of the bulb (with use, the electrodes burn away and the gap increases causing an amperage drop and a rise in voltage); and 4, To reduce the voltage at the lamp head as required.

Ballast units, particularly for the higher wattage MH lamps, can be big and heavy and require trolleys to move them around. In most cases they must be sited near the foot of the lamp stand.

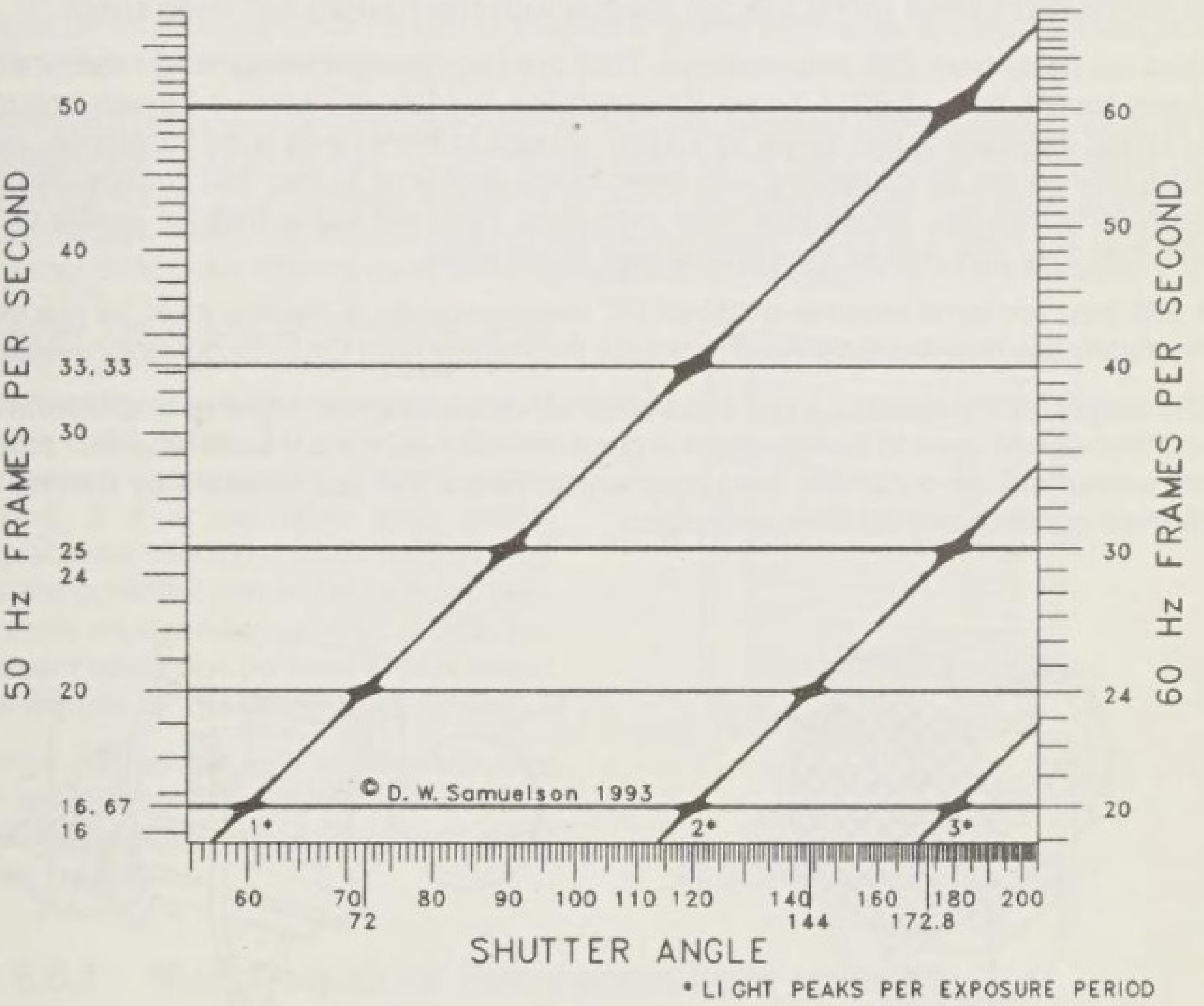


METAL HALIDE LAMP: 1 Power distribulion unit; 2. Ballast unit; 3. Lamp head

With a normal ballast unit MH lamps emit a light which pulses at twice the rate of the AC supply frequency. Off a 60Hz supply a MH lamp will produce 120 bright pulses of light, interspersed with 120 periods of near darkness, every second. Such lighting can only be used at frame rates which are divisible into twice the frequency or with a camera speed and shutter combination which creates an exposure time which exactly equals one or more complete pulse cycles.

Examples of the 'divisible into twice the AC frequency' rule are, (a) with a 60 Hz power supply, 12, 15, 20, 24, 30, 40 and 60 fps and (b) with 50 Hz, 10, 12.5, 16.666, 20, 25, 33.333 and 50 fps. If the camera can be synchronized with a single pulse of light then 120 or 100 fps are also possible.

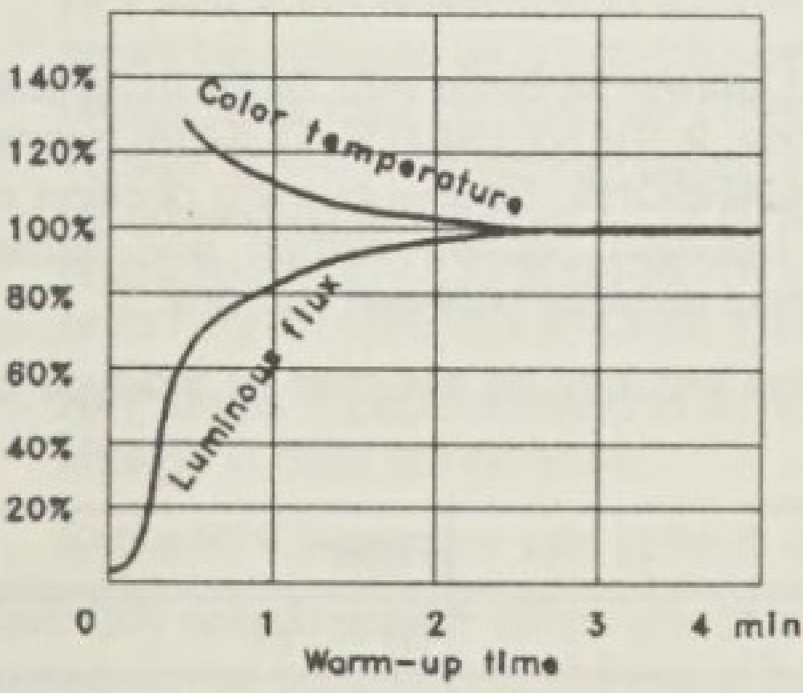
IN ALL CASES SAFE MH LIGHTING OPERATION IS DEPENDENT UPON EXTREMELY ACCURATE AND STABLE POWER SUPPLIES AND EQUALLY PRECISE CAMERA SPEEDS. The AC power must either be off a nation-wide power grid where the accuracy can be guaranteed, or off a crystal controlled alternator. The camera must either be crystal speed controlled or be slaved or driven by the AC power supply.



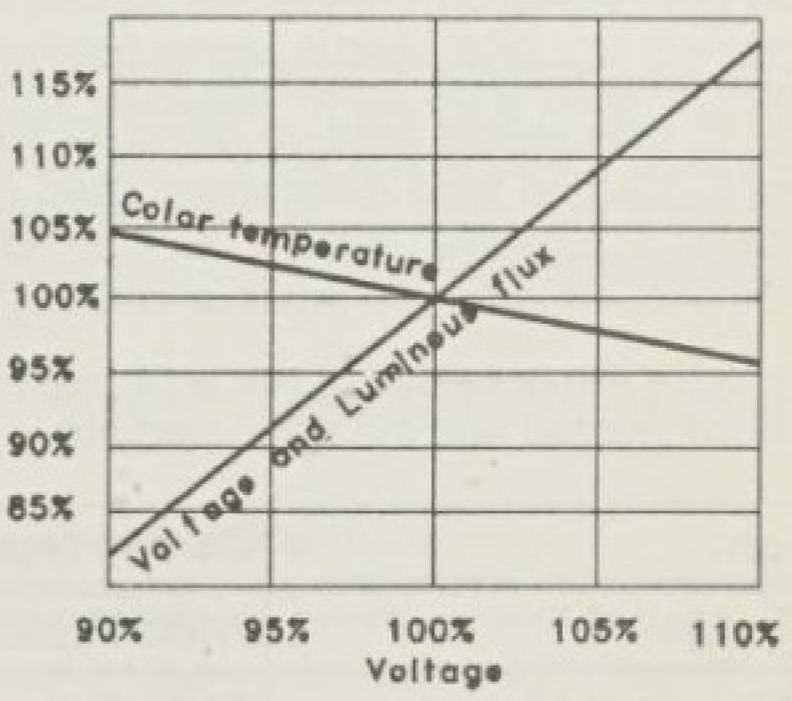
WINDOWS OF SAFE MH LIGHTING OPERATION FOR 50 AND 60Hz POWER SUPPLIES. The horizontal lines are safe camera speeds irrespective of shutter openings, the oblique lines are safe shutter angle/camera speed combinations. The nodes where the lines cross are the SAFEST windows of operation.

Alternatively, a 'Flicker Free' ballast may be used. Most 'Flicker Free' ballasts operate by converting the current to DC and then changing it back to AC either at a frequency rate well above the normal filming frame rate or with a 'square wave' waveform, effectively filling in the periods of no lighting. A few ballasts will operate directly off a DC supply.

MH lamps require an initial two or three minute warm-up period during which time the brightness increases and the color temperature reduces to the working level. A power supply below the rated voltage will result in reduced lamp brightness and *increased* color temperature, and vice versa if the voltage is too high.



MH WARM-UP PERIOD. Light output and color temperature v time.



MH LIGHT OUTPUT AND COLOR TEMPERATURE VARIATIONS WITH APPLIED VOLTAGE.

Unshielded MH lamps produce dangerous UV light. For this reason MH lighting units are fully sealed and have a close fitting glass front. They must never be used with the glass front open.

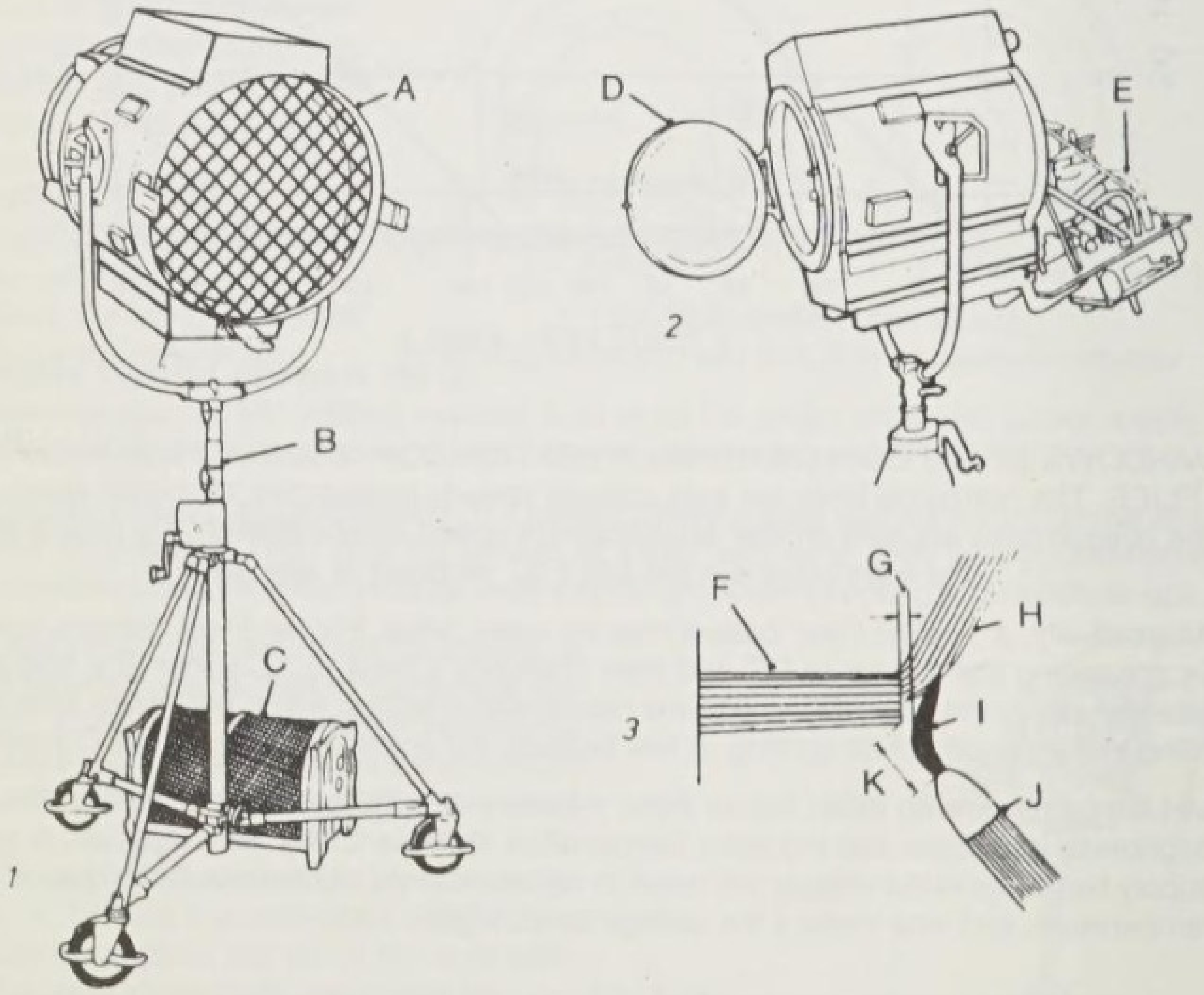
14.5.5 Arc light

Carbon arc lighting is as old as cinematography itself. To this day, when a great deal of controllable light is required from a small point source there is still little to beat it. A single 225 amp 'brute' arc light can fill the shadows of bright sunlight over a wide area or create its own sunlight effect giving a single shadow with sharp edges and deep shade.

Most arc lights burn 225 amp carbons. They are heavyweight equipment, require a DC power supply, heavy cables, heavy transportation, are labour intensive (usually one man to attend only one or two lamps at a time), if used indoors need good ventilation, need extra time to set up compared with other lamps and time to trim and change carbons every forty minutes. Those who have ever used them will argue that the quality of the light that they give makes the effort all well worth while.

A 225 amp arc lamp requires a 73 volt DC electric supply. A resistor must be placed in the supply line near the lamp head to reduce the voltage from the 115v normally available.

The supply is connected to a pair of carbons which are touched together to strike the arc and then drawn apart to create a light of great intensity. As the arc burns and the carbons are consumed, an automatic feed mechanism keeps the gap constant by moving the carbons continuously towards each other.



1. 225 amp 'BRUTE' CARBON ARC LAMP: A. Lightweight Brute with 24 3/4 in. fresnel lens, B. Lightweight wind-up stand, C. Resistance: 2. 'BABY BRUTE': D. 14 in. fresnel lens, E. Carbon feed mechanism tilted out, 3. CARBONS: Normal burning position of carbons F. Positive carbon, G. Correct gap between positive carbon and flame, H. Smoke, I. Flame, J. Negative carbon, K. Correct distance between carbons.

The color temperature of the light from a carbon arc may be selected by the type of carbons burned and the filter used viz:

Light	Carbon type	Filter
'Daylight'	White Flame	WFG, Y1
3200K (213 Mireds)	White Flame	MT2+Y1, MT/Y, Full CTO
3200K (213 Mireds)	Yellow Flame	YF

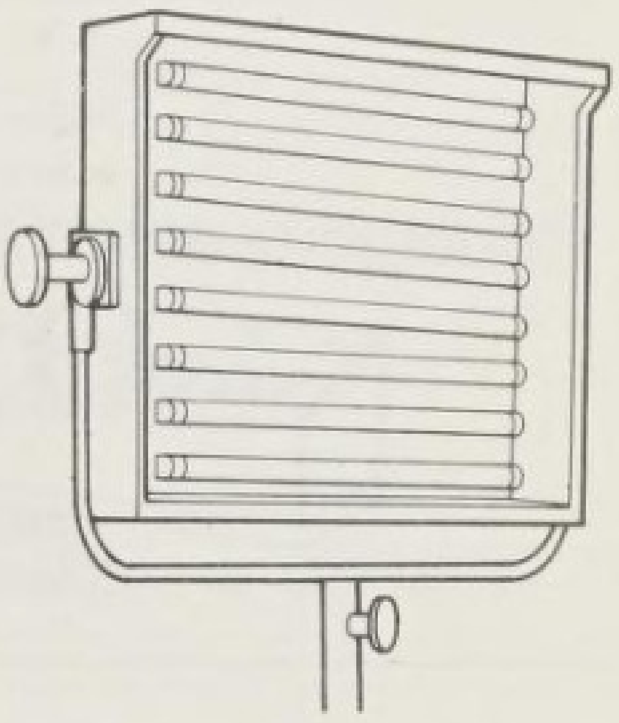
14.5.6 Fluorescent light

Domestic and industrial type fluorescent lighting abounds in many situations where location filming is carried out - airports, factories, offices, hospitals, supermarkets, etc. - or may be introduced for its own benefits. Fluorescent lighting is soft and kind, it creates little or no heat and is ideal for use in situations where ventilation is either inadequate, noisy or would be expensive.

Fluorescent light has a peculiar spectrum with narrow spikes of intense color in the green and blue regions (see 14.4.2). To the human eye it looks like a normal light balance but to film there may be increased exposure to some colors and little exposure to others. Many modern filmstocks incorporate special narrow-band filters to restore the balance. For other filmstocks filtering must either be applied to the source or to the camera.

Because the colors of individual fluorescent tubes can differ widely it is important to ensure that only one type of tube is used. While it is safer not to mix fluorescent with tungsten or metal halide lighting, if it is inevitable then photographic tests should be made beforehand. It is not sufficient just to use a color temperature meter. Alternatively, similar fluorescent tubes can be used in floor stand type fixtures for the low level fill lighting.

Normal fluorescent light is discontinuous and like Metal Halide lighting can strobe or pulse when film is shot at non-compatible frame rates.



FLUORESCENT FILL-LIGHT

14.5.6.1 High frequency fluorescent light sources

Special fluorescent lamps, incorporating high frequency ballasts (28 kHz, or more), are available for film and television production purposes.

The advantages of this type of lighting are as follows:

More light for less power. High frequency fluorescent (HFF) lamps produce 70 - 100 lumens per watt compared to 25 from a typical tungsten light and are a more efficient means of producing a soft ambient lighting than either bounce or diffusion.

Less heat per watt of electricity. HFF lamps convert 33% of their input energy to usable light compared to only 10% by tungsten light, 50% of which is radiated in the light beam. This means that less ventilation is required (consuming more power and, very often, creating a noise problem), artists and heat sensitive products are more comfortable and lighting units can be placed close to delicate surfaces (such as the interior roof of an automobile) without fear of causing damage.

HFF lamps are flicker-free at any frame rate and off any power frequency. They may safely be powered off a non-frequency regulated power supply. 120 volt electronic ballast units may be powered off any voltage between 75 and 160 volts, the high voltage type off any voltage between 170 and 260. The electronic ballast units work by converting the normal 50 or 60 Hz input power first to DC and then to the very high frequency AC. 12 and 120 volt DC units are also available. The electronic ballast units may be sited at a distance from the bulb.

HFF lamps may be dimmed to 20% of their maximum light output without noticable change in color temperature.

Some HFF lamps are said to have a bulb life of 15-20000 hours.

Generally speaking HFF lamps are shadow free and give a broad spread of light. The spread can be controlled by the use of a honeycomb type screen or a micro-fresnel type 'filter' screen may be used concentrate the light and produce a soft shadow.

HFF lamps require a 30 second warm-up period afterr which they may be switched off and on instantaneously. They will not work in very cold ambient temperatures unless pre-heated.

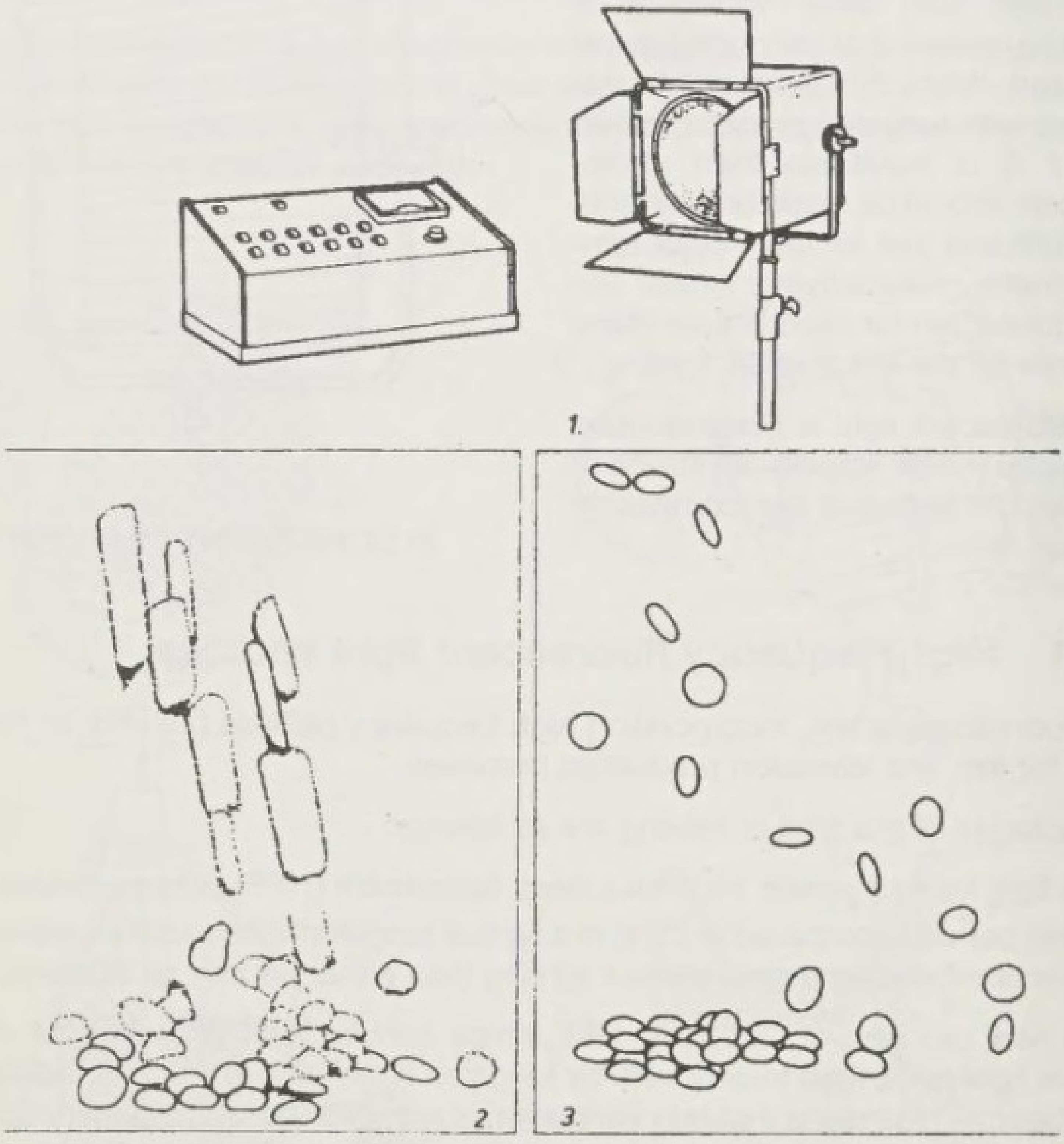
HFF lamps are available in a wide range of color temperatures as well as in narrow band blue, green and UV for composite cinematography purposes. They may be mixed with tungsten or metal halide lighting with care and with pre-production photographic tests.

14.5.7 Strobe light

Strobe lighting, with a single ten millionth of a second exposure for each frame, gives a crispness to fast moving detail that makes each and every particle almost touchable.

Another advantage is that strobe lights are cold and thus very useful when filming biological or botanical specimens or ice cream or anything else that will melt, wilt or otherwise deteriorate under the effect of hot incandescent lighting.

They are particularly advantageous for filming a cascade of small, crisp objects or a flow of frothy liquid and not only making them look good but also enabling a freeze frame to be done at the end which makes each object or drop look as though it could be picked off the screen. Strobe lights are much used in the TV commercials industry when filming pack shots of crunchy cornflakes or ice cold colas.



1. STROBE LIGHT CONTROL CONSOLE AND LAMP HEAD; 2. FALLING BEANS FILMED BY NORMAL LIGHTING; 3. THE SAME BEANS PHOTOGRAPHED BY STROBE LIGHTING.

Because each exposure period is so brief each flash must be synchronized directly with the camera. All the major camera manufacturers can supply an electronic interface or else an electric contact can be fitted to the camera inching knob or other part that rotates once every frame.

Strobe consoles also have a facility for plugging in 'viewfinder lights', lights which flash 180° out of synchronization with the principal lights to give illumination during the viewing period. These lights must be switched off when checking synchronization. An intermediate flash is also advantageous when filming people, because 48 flashes per second is found to be far less disturbing than 24.

The light from strobe lights have a color temperature of about 6000K (167 Mireds) and the power is measured in joules.

Many people, particularly those prone to epileptic fits, find low frequency (12 - 24 Hz) disturbing. 17 flashes per second is said to be particularly dangerous and should be avoided.

15 THE MATHEMATICS OF CINEMATOGRAPHY

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15.1 INTRODUCTION TO THE MATHEMATICS OF CINEMATOGRAPHY

There is much arithmetic involved in motion picture film production, even after sorting out the practical from the theory. For some it is fairly straightforward calculations such as 'how many feet of film will pass through a 35mm camera in 1 minute at 120 fps?' For others it may be 'how far back will the camera need to be to take in a set 40 feet wide on a 20mm lens to fill an Academy frame?' or 'if the far person on a focus split is 12 ft away how close can the near person be?' And so on.

Traditionally, the industry has relied upon a mixture of look-up tables, slide calculators and experience to predict such variables of film making as, say, lens depth of field or film running times; but such methods are very limiting. Depth of field tables are not available for every lens focal length or focus distance, neither are film running time tables available for every length of film at every frame rate. Much better, in this day and age, to calculate the answers exactly, using the tools of our times, the pocket electronic calculator and the palmtop computer.

For most calculations an electronic calculator the size of a credit card will suffice but for a few (mainly those involving lens angles) a 'scientific' calculator (or a computer) is required. However, if the procedures given in this section of this book are followed carefully, no knowledge of trigonometry, logarithms or computer programming, etc., is required to find the answers.

All calculations are presented in a similar manner, viz:

1. A short preamble, where necessary.
2. The appropriate equation (no symbols are used) shown in both the more traditional method (using dividends and divisors, etc.) and longitudinally (using nested brackets etc.) as used to input a calculation into a computer. Note: In the dividend/divisor type of equation × and ÷ are used to indicate multiply and divide and in the longitudinal method * and / are used. Be careful not to confuse divide (÷) and plus (+) signs. When the printing is very small they sometimes look very similar.
3. An example problem.
4. A table showing the calculator 'key sequence', i.e. the sequence in which the appropriate figures should be entered and the function keys touched. This is illustrated with figures from the example problem, showing the numbers displayed on the calculator at each stage.
5. The answer to the example problem.
6. A table showing the sequence of Computer Input operations comprising the equation in computer format, the values of the example problem, the equation set out with the values exactly as it should be entered into the computer, and the answer.
7. Where a more precise, but more complicated, equation is possible but which would be somewhat laborious to input into a pocket calculator, this is shown as an additional Computer Input method.
8. A table, or tables, of constants, where appropriate.
9. Look-up tables of calculations and/or graphs, where appropriate.

Note: This book does not set out to be a text book of arithmetic or even an authoritative manual on the mathematics involved in the particular aspects covered. Instead, it is intended as a means to make it possible for practical technicians who may have no knowledge of arithmetic, or even any desire to have such knowledge, to make calculations, with the aid of a calculator, to use in their everyday lives.

15.1.1 Notes about calculators

Not all calculators operate in the same manner and readers are advised both to read the calculator's manual before starting to make calculations and then to key-in the sample problems before entering real data in order to check that the sequence of entry works on their particular calculator and that they understand what is required.

Priority is given to the keying-in sequences required for the most simple of calculators. Most of these allow a chain of calculations to be input, usually needing to touch the = (equals) key only at the end of the calculation. Where a scientific calculator is used it may be found necessary to touch the = key at intermediate stages of the calculation. At the outset the reader should find, by trial and error, what works and what does not work, on a particular calculator.

For most problems electronic calculators and computers calculate to a much greater degree of accuracy than is necessary for practical applications and a habit should be made to read the answers to the first few significant figures only.

Occasionally it will be noted that computers produce a very slightly different answer from calculators, and even some calculators will differ slightly. This is because some machines, especially computers, work to many more decimal places or round off numbers in a different manner. The differences, however, are very unlikely to be significant to the real world of film making.

Very often there is more than one way of going about making a calculation. In this book the method described is what works best for the author. There may well be other ways which are more orthodox or work better for other people. Readers are welcome to use the example problems as a basis for experimentation.

'Scientific calculators', which incorporate many more functions, including trigonometric functions which are necessary when calculations involving angles are made, usually require the = key to be pressed before using a function key or else the function is applied only to the last figure entered. The user should check which way their particular calculator operates.

Throughout this book, where it is necessary to use a function key, and the calculation does not necessitate the use of a scientific calculator, both series of keystrokes are shown and those required by a scientific calculator are marked with a '§' sign.

15.1.1.1 Know your calculator

Even simple calculators often have facilities that the casual user is not aware of, let alone ever uses. This is especially so as not all calculators operate in exactly the same manner. It is, therefore, well worthwhile to explore your own machine to see if it has hidden virtues, and if so, to try them out and remember how to use them next time the opportunity comes along. It may even be worth rereading the instruction manual.

The 'constant' facility, for example, enables a common number to be used in multiplication, division, addition or subtraction calculations without the need to constantly re-enter the common number.

On some machines the method involves pressing the operator (+, -, ÷, ×) twice. On many machines a letter 'K' will appear in the corner of the display to show it is in the constant mode.

Constant Multiplication

When multiplying the constant is entered first

Key Sequence	Example	Display
Enter constant	2	2
Touch multiply	×	2
Touch multiply	×	K 2
Enter variable	3	K 3
Touch equals	=	K 6
Enter next variable	4	K 4
Touch equals	=	K 8
And so on		

Constant Division

When dividing, adding or subtracting it is the constant that is entered second viz:

Key Sequence	Example	Display
Enter first variable	10	10
Touch divide	÷	10
Enter constant	2	2
Touch equals	=	5
Enter next variable	20	20
Touch equals	=	10
And so on		

Constant addition and subtraction operate the same way round as division.

Exponents (the square, cube and power of a number)

Key Sequence	Example	Display
Enter number	2	2
Touch multiply	×	2
Touch equals	=	4
Touch equals	=	8
And so on		

Note: It is not possible to go beyond a power of 5 with an eight character display.

Reciprocal

Key Sequence	Example	Display
Enter a number	2	2
Touch divide	÷	2
Touch equals	=	0.5

15.1.2 Notes about computers

Computers, even the very small ones which fit into the palm of the hand, have many advantages over calculators, even when used to make a straightforward calculation.

This is particularly so when making long calculations which require many entries and the need to use the memory facility. With a computer it is possible to enter the entire calculation and examine the input for correctness before pressing the Enter key.

Another advantage is the possibility of repeating calculations, with slightly differing inputs, without the need to re-enter everything. Even greater precision and flexibility is possible using spreadsheet programs, such as Lotus 123 or the like. With these it is possible to compile, say, a set of depth of field tables to the precise focal lengths of a complete set of available lenses and to customize circles of confusion and focus distances, etc.

Many computers and computer programs (especially spreadsheets) have useful mathematical functions, including INT, MOD and ROUND, which are not available on calculators.

The function INT reduces a number which has decimal places to just the whole number, i.e. INT(24.114615) would produce 24.

MOD takes a number and a divisor and returns the remainder. MOD(24.114615,12) would return .114615 and MOD(24.114615,12)*12 would return the number of inches, i.e. 1.37538.

ROUND 'rounds' a number off to any number of decimal places or to the nearest hundred or thousand, etc. ROUND(24.114615,2) would become 24.11. Numbers that end with the value of 5 or more are 'rounded' upwards.

Other mathematical functions used in this book, where necessary, are ATN (inverse tangent), LOG (log of a number, base 10), SQR (square root of a number), and TAN (Tangent of a number).

The look-up tables published in this book have been generated on a Lotus 123 spreadsheet using the algorithms shown in the text.

15.1.3 Abbreviations used in the text

The abbreviations used in the various equations in this book are consistent throughout. They are not necessarily the same as those commonly used elsewhere:

Ω	Ohms (Resistance)
Ρ	Rho (Resistivity)
α	Alpha (Temperature coefficient)
μ	Mu (1/1,000,000)
A	Amperes
AC	Alternating current
Af	Anamorphic lens focal length
Alt	Altitude
AO	Anamorphic object width
AR	Aspect ratio
ASR	Anamorphic Squeeze Ratio
BA°	Beam angle°
CC	Circle of confusion
Ccsa	Conductor cross-sectional area
CD	Film core diameter
CFL	Combined focal length
Cfps	Camera frames per second
Cl	Conductor length
CM	Circular mils
Cn	Number of conductors
CPF	Combined point of focus
CRT	Camera running time
°C	Degrees Celsius
D	Distance or focus distance
DC	Direct current
DND	Distance without a diopter
DP	Diopter Power
DWD	Distance with a diopter
ET	Event time
f	Lens focal length
F	Point of focus
fD	Far distance
FNC	Fixed nodal constant
fpf	frames per foot
fpm	frames per meter
fps	frames per second (camera speed)
ft	feet
°F	Degrees Fahrenheit
hrs	hours
H	Hyperfocal distance
Hz	Hertz (AC electricity frequency)
I	Image size
kVA	Kilo Volt Amps
kW	Kilo Watts
L	Length
LB	Lamp brightness
Le	Lens extension
LPEP	Lighting peaks per exposure period
LSD	Lens Scale Distance
L°	Lens angle (degrees)
LI	Luminous intensity
m	meters
M	Magnification factor
Mf	Maximum focal length
MH	Metal Halide (lighting)
min	minutes
mm	millimeters
mS	Minimum aperture
n	number
nD	Near distance
ND	New distance
NET	New exposure time
Nff	New filter factor
Nfps	New camera speed
NLB	New lamp brightness
NLL	New light level
NND	New ND filter density
NR	New Resistance
NS	New stop
NSA	New shutter angle
NT	New Temperature
O	Object size
OD	Old distance
OEI	Old Exposure Index
OET	Old exposure time
Off	Old filter factor
Ofps	Old camera speed
OLB	Old lamp brightness
OLL	Old light level
OND	Old ND filter density
OR	Old Resistance
OS	Old stop
OSA	Old shutter angle
OT	Old Temperature
PBI	Peak beam intensity
Pf	Power factor
Pfps	Projector frames per second
PH	Picture height
PRF	Power rating factor
PRT	Projector running time
PW	Picture width
R	Resistance
RD	Film roll diameter
RL	Film roll length
ROS	Real object speed
S	Stop (lens aperture), f or T
SA°	Shutter angle°
sec	seconds
SI	Scene illumination
SM	Size of Miniature
SO	Size of Original
SS	Screen speed
ST	Screen time
TH	Film thickness
TR	Temperature Rise
TS	True speed
V	Volts
V_1	Original voltage
V_2	Terminal voltage
W	Watts
Vd	Voltage drop
≈	Approximately equal to (i.e., for all practical purposes)

15.1.4 Conversions

15.1.4.1 Sample calculation

The following very simple calculations illustrate the methodology of this section.

All conversion factors listed in Tables 1 and 2 are expressed as multiplication factors and may be used as follows:

$$\text{Inches} = \text{millimeters} \times 0.03937$$

$$\text{Millimeters} = \text{inches} \times 25.4$$

or

$$in = mm*0.03937 \text{ and } mm = in*25.4$$

where in = inches and mm = millimeters.

Example: The lens to be used has a focal length of 75mm. To make a depth of field calculation in Imperial measurements it is necessary to convert that focal length to inches before making the calculation.

Key Sequence	Example	Display
Enter millimeters	75	75
Touch multiply	×	75
Enter conversion factor (Table 2)	0.03937	0.03937
Touch equals	=	2.95275

Answer: 2.95275, but for most practical purposes, ≈ 3 inches.

Computer input
mm*c
Let mm = 75 and c = 0.03937 (Table 2)
75*.03937
2.95275

Alternatively, it is equally possible to convert millimeters to inches by dividing the number of millimeters by 25.4 viz:

Key Sequence	Example	Display
Enter millimeters	75	75
Touch divide	÷	75
Enter conversion factor (Table 1)	25.4	25.4
Touch equals	=	2.9527559

15.1.4.2 Feet and inches to meters

$$\text{meters} = \frac{\text{feet} \times 12 + \text{inches}}{39.37}$$

or

$$m = ((ft*12) + in)/39.37$$

where m = meters, ft = feet, and in = inches.

Example: A lens scaled in meters is to be focused on an object at 7ft 4ins. At what distance should it be set?

Key Sequence	Example	Display
Enter feet	7	7
Touch multiply	×	7
Enter conversion factor	12	12
Touch plus	+	84
Enter inches	4	4
Touch divide	÷	88
Enter conversion factor (Table 2)	39.37	39.37
Touch equals	=	2.2352045

Answer: ≈ 2.24 meters.

Computer input
((ft*12)+in)/39.37
Let ft = 7 and in = 4
((7*12)+4)/39.37
2.23520447

15.1.4.3 Meters to feet and inches

$$feet = meters \times 3.2809$$

Example: What is the equivalent in feet and inches of 7 meters 35 centimeters?

Key Sequence	Example	Display
Enter meters	7.35	7.35
Touch multiply	x	7.35
Enter conversion factor	3.2808	3.2808
Touch equals	=	24.11388

Answer: 24.114615 feet.

To convert decimal parts of a foot into inches subtract the number of feet and multiply the remainder by 12 viz:

Touch minus	-	24.11388
Enter number of feet	24	24
Touch multiply	x	0.11388
Enter conversion factor	12	12
Touch equals	=	1.36656

Answer: 24 feet 1.37538 inches.

Computer input
m*0.03937
Let m = 7.35
ft = 7.35*3.2808
ft = 24.11388

followed by

ft = INT(f) = 2
and in = MOD(f,12) = 11.36656
or in = (f-(INT(f))*12 = 1.36656
2 ft. 11.433 in.

15.1.4.4 Decimal feet to feet and inches

Many calculations, like those above, are done in feet with an answer finishing up as so many feet plus decimal parts of a foot.

To save the necessity of subtracting the whole numbers of feet and multiplying the remainder by 12 to find the number of inches it is very often quicker to use Tables 4 and 5 which show decimal parts of a foot as inches and inches as decimal parts of a foot.

15.1.5 Conversion factors

15.1.5.1 Table 1. Imperial & U.S. to Metric

Multiply number of	by	to obtain equivalent number of
	LENGTH	
Thousandths of 1 in.	25.4	microns
Inches (in.)	25.4	millimeters (mm)
Inches	2.54	centimeters (cm)
Inches	0.0254	meters (m)
Feet (ft.)	304.8	millimeters
Feet	30.48	centimeters
Feet	0.3048	meters
Yard (yd)	0.9144	meters
Fathoms (6ft)	1.8288	meters
Miles (land: 5,280ft)	1.609344	kilometers (km)
Miles (UK sea: 6,080ft)	1.853184	kilometers
Miles, int. nautical	1.852	kilometers (km)
	AREA	
Sq.inches (in^2)	645.16	sq. millimeters (mm^2)
Sq.inches	6.4516	sq. centimeters (cm^2)
Sq. feet (ft^2)	929.0304	sq. centimeters
Sq. feet	0.092903	sq. meters (m^2)
Sq. yards (yd^2)	0.836127	sq. meters
Acres	4046.86	sq. meters
Acres	0.404686	hectares (ha)
Acres	0.004047	sq.kilometers (kmt^2)
Sq. miles	2.58999	sq. kilometers
	VOLUME AND CAPACITY	
Cu. inches (in.^{3})	16.387064	cu. centimeters (cm^3)
Cu. inches	0.576744	UK fluid ounces
Cu. inches	0.554113	US liquid ounces
UK pints	34.6774	cu. inches
UK pints	0.5683	liters (l)
UK gallons	4.54609	liters
US gallons	3.785	liters
Cu. feet (ft.^{3})	28.317	liters
Cu. feet	0.028317	cu. meters (m^3)
UK bushels	0.3637	hectoliters (hl)
US bushels	0.3524	hectoliters
UK gallons	1.20095	US gallons
US gallons	0.832674	UK gallons
UK bulk barrels	36	UK gallons
UK bulk barrels	43.2342	US gallons
UK bulk barrels	0.1637	cu. meters
	WEIGHT (mass)	
Grains (gr)	64.79891	milligrams (mg)
Ounces, avoirdupois (oz)	28.3495	grams (g)
Ounces, troy (oz tr)	31.1035	grams
Ounces, avoirdupois	0.9115	ounces, troy
Pounds, avoirdupois (lb)	435.59237	grams
Pounds, avoirdupois	0.45359	kilograms (kg)
Hundredweights (cwt)	0.05	long tons
Hundredweights	0.508023	metric quintals (q)
Short tons (2,000 lb)	0.892857	long tons
Short tons	0.907185	tonnes (t)
Long tons (2,240 lb)	1.12	short tons
Long tons	1.01605	tonnes
	VELOCITY	
Feet per minute	5.08	millimeters per sec.
Miles per hour	1.609344	kilometers per hour
Miles per hour	0.868976	international knots
International knots	1.15078	miles per hour
International knots	0.514444	meters per sec.
	FUEL CONSUMPTION	
Miles per UK gallon	0.354006	kilometers per liter
Miles per US gallon	0.425144	kilometers per liter
Miles per UK gallon	0.00354	liters per 100 kilometers
Miles per US gallon	0.004251	liters per 100 kilometers
UK gallons per mile	282.481	liters per 100 kilometers
US gallons per mile	235.215	liters per 100 kilometers
UK gallons per hour	4.54609	liters per hour
US gallons per hour	3.78541	liters per hour
	LIGHT	
Foot candles or Lumens per sq. foot	10.76639	lux or lumens per sq. meter
Foot lamberts	3.42626	candelas per sq. meter
Candelas per sq. ft.	10.7639	candelas per sq. meter
	PLANE ANGLE	
Degrees	0.0174533	radians
Grades	0.0157089	radians
	TEMPERATURE	
Degrees Fahrenheit	0.555556 after subtracting 32	degrees Celsius (Centigrade)

15.1.5.2 Table 2. Metric to Imperial & U.S.

Multiply number of	by	to obtain equivalent number of
	LENGTH	
Microns	0.03937	thousandth of 1 in.
Millimeters	0.03937	inches
Millimeters	0.0032808	feet
Centimeters	0.3937	inches
Meters	39.3701	inches
Meters	3.2808	feet
Meters	1.0936	yards
Meters	0.54681	fathoms
Kilometers	0.62137	miles (land)
Kilometers	0.53961	miles (UK sea)
Kilometers	0.53996	miles (international nautical)
	AREA	
Sq. millimeters	0.00155	sq. inches
Sq. centimeters	0.1550	sq. inches
Sq. meters	10.7639	sq. feet
Sq. meters	1.19599	sq. yard
Hectares	2.47105	acres
Sq. kilometers	247.105	acres
Sq. kilometers	0.3861	sq. miles
	VOLUME AND CAPACITY	
Cu. centimeters	0.0610237	cu. inches
Cu. centimeters	0.0351951	UK fluid ounces
Cu. centimeters	0.0338140	US liquid ounces
Liters	61.0237	cu. inches
Liters	0.035315	cu. feet
Liters	1.75975	UK pints
Liters	2.11338	US liquid pints
Liters	0.21997	UK gallons
Liters	0.26417	US gallons
Hectoliters	21.997	UK gallons
Hectoliters	26.417	US gallons
Hectoliters	2.750	US bushels
Hectoliters	2.838	UK bushels
Cu. meters	35.3147	cu. feet
Cu. meters	1.30795	cu. yards
Cu. meters	219.969	UK gallons
Cu. meters	264.172	US gallons
Cu. meters	6.11025	UK bulk barrels
	WEIGHT	
Milligrams	0.01543	grains
Grams	0.03527	ounces, avoirdupois
Grams	0.03215	ounces, troy
Kilograms	35.274	ounces, avoirdupois
Kilograms	32.151	ounces, troy
Kilograms	2.20462	pounds, avoirdupois
Metric quintals	220.462	pounds, avoirdupois
Tonnes	2,204.62	pounds, avoirdupois
Tonnes	1.10231	short tons
Tonnes	0.984207	long tons
	VELOCITY	
Millimeters per sec.	0.196850	feet per minute
Kilometers per hour	0.62137	miles per hour
Kilometers per hour	0.53996	international knots
Miles per hour	0.868976	international knots
Miles per hour	1.94384	international knots
	FUEL CONSUMPTION	
Kilometers per liter	2.82481	miles per UK gallon
Kilometers per liter	2.35215	miles per US gallon
Liters per 100 kilometers	0.00354	UK gallons per mile
Liters per 100 kilometers	0.00425	US gallons per mile
Liters per 100 kilometers	282.481	miles per UK gallon
Liters per 100 kilometers	235.215	miles per US gallon
Liters per hour	0.21997	UK gallons per hour
Liters per hour	0.26417	US gallons per hour
	LIGHT	
Lux or lumens per sq. meter	0.092903	Foot candles or lumens per sq. foot
Candelas per sq. meter	0.092903	Candelas per sq. foot
Candelas per sq. meter	0.291863	foot lamberts
	PLANE ANGLES	
Radians	57.2958	degrees
Radians	63.6620	grads or gons
	TEMPERATURE	
Degrees Celsius (Centigrade)	1.8 and add 32	degrees Fahrenheit

15.1.5.3 Table 3. Arithmetical formulae

$pi(\pi) = 3.1416, 2\pi = 6.2832, \pi^2 = 9.8696, \sqrt{\pi} = 1.772454, \pi/4 = 0.7854$

AREA

Circle = Radius^2 × π = diameter^2 × 0.7854.
Sector of circle = Length of arc × 1/2 radius
Segment of circle = Area of sector - area of triangle
Ellipse = Long axis and short axis × 0.7854
Parabola = 2/3 base × height
Parallelogram = Base × height
Regular Polygon = 1/2 radius of inscribed circle × side × number of sides
Irregular Polygon = Divide into triangles, find area of each and add
Rhomboid or Rhombus = Base × height
Square = Side^2
Trapezium = 1/2 base × height
Triangle = 1/2 base × height

LENGTH

Circumference of circle = Diameter × π
Diameter of circle equal in area to square = Side × 1.1284
Arc of circle = 0.01745 radius × angle in degrees × radius
Side of square and equal in area to circle = Diameter × .8862
Side of square inscribed in circle = Diameter × 0.707

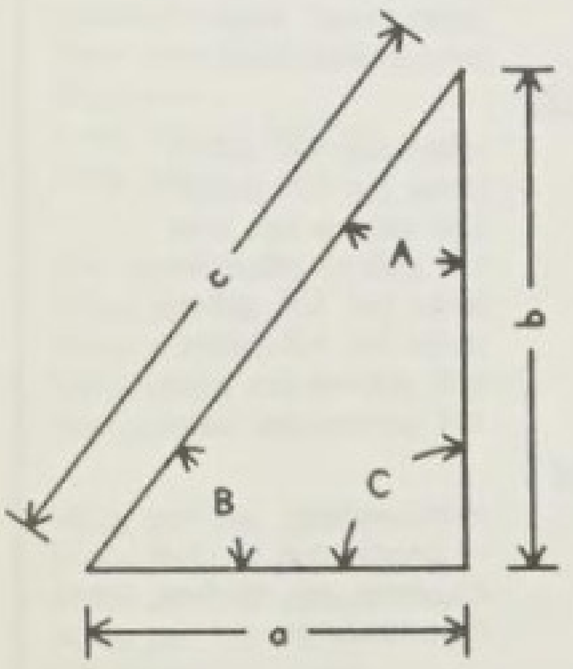
SURFACE

Cone = 1/2 slant height × diameter of base × π + area of base
Cylinder = Diameter × length × π + area of ends
Prism = Length × perimeter + area of two ends
Pyramid = 1/2 slant height × perimeter + area of base
Sphere = π × diameter^2

VOLUME

Cone = 1/3 area of base × perpendicular height
Cylinder = Area of base × height
Paraboloid = 1/2 volume of circumscribing cylinder
Prism = Area of base × height
Pyramid = 1/3 area of base × perpendicular height
Sphere = 1.33 × π × radius^3

15.1.5.4 Trigonometry of right triangles



$$Sin\ A = \frac{opposite\ side}{hypotenuse} = \frac{a}{c}$$

$$Cos\ A = \frac{adjacent\ side}{hypotenuse} = \frac{b}{c}$$

$$Tan\ A = \frac{opposite\ side}{adjacent\ side} = \frac{a}{b}$$

$$a^2 = c^2 - b^2$$

$$b^2 = c^2 - a^2$$

$$c^2 = a^2 + b^2$$

Given a and b, find A, B, c and area

$$tan\ A = \frac{a}{b},\quad tan\ B = \frac{b}{a},\quad c = \sqrt{a^2+b^2},\quad area = \frac{ab}{2}$$

Given a and c, find A, B, b and area

$$sin\ A = \frac{a}{c},\quad cos\ B = \frac{b}{c},\quad b = \sqrt{c^2-a^2},\quad area = \frac{a\sqrt{c^2-a^2}}{2}$$

Given A and a, find B, b, c and area

$$B = 90^\circ - A\ ,\quad b = a\cot A\ ,\quad c = \frac{a}{\sin}A\ ,\quad area = \frac{a^2\cot A}{2}$$

Given A and b, find B, a, c and area

$$B = 90^\circ - A\ ,\quad a = b\tan A\ ,\quad c = \frac{b}{\cos A}\ ,\quad area = \frac{b^2\tan A}{2}$$

Given A and c, find B, a, b and area

$$B = 90^\circ - A\ ,\quad a = c\sin A\ ,\quad b = c\cos A\ ,\quad area = \frac{c^2\sin 2A}{4}$$

15.1.6 Feet/meters look-up tables

15.1.6.1 Decimal feet

TABLE 4. DECIMAL PARTS OF 1 FOOT AS INCHES

0.1 foot	=	1.2 inches
0.2 foot	=	2.4 inches
0.3 foot	=	3.6 inches
0.4 foot	=	4.8 inches
0.5 foot	=	6.0 inches
0.6 foot	=	7.2 inches
0.7 foot	=	8.4 inches
0.8 foot	=	9.6 inches
0.9 foot	=	10.8 inches

TABLE 5. INCHES AS DECIMAL PARTS OF 1 FOOT

1 inch	=	0.0833 foot
2 inches	=	0.1667 foot
3 inches	=	0.25 foot
4 inches	=	0.333 foot
5 inches	=	0.4167 foot
6 inches	=	0.5 foot
7 inches	=	0.5833 foot
8 inches	=	0.66 foot
9 inches	=	0.75 foot
10 inches	=	0.833 foot
11 inches	=	0.9167 foot

15.1.6.2 Meters as feet and inches look-up table

TABLE 6. DECIMAL PARTS OF 1 METER AS INCHES

0.1 meters	=	3.9 inches
0.2 meters	=	7.9 inches
0.3 meters	=	11.8 inches
0.4 meters	=	15.7 inches
0.5 meters	=	19.7 inches
0.6 meters	=	23.6 inches
0.7 meters	=	27.6 inches
0.8 meters	=	31.5 inches
0.9 meters	=	35.4 inches
1.0 meters	=	39.4 inches

TABLE 7. METERS AS FEET AND INCHES

1 meter	=	3 ft	3.4 in
2 meters	=	6 ft	6.7 in
3 meters	=	9 ft	10.1 in
4 meters	=	13 ft	1.5 in
5 meters	=	16 ft	4.8 in
6 meters	=	19 ft	8.2 in
7 meters	=	22 ft	11.6 in
8 meters	=	26 ft	3 in
9 meters	=	29 ft	6.3 in
10 meters	=	32 ft	9.7 in

15.1.6.3 Feet as meters look-up table

TABLE 8. FEET AS METERS

1 foot	=	0.30 meters
2 feet	=	0.61 meters
3 feet	=	0.91 meters
4 feet	=	1.22 meters
5 feet	=	1.52 meters
6 feet	=	1.83 meters
7 feet	=	2.13 meters
8 feet	=	2.44 meters
9 feet	=	2.74 meters
10 feet	=	3.05 meters
15 feet	=	4.57 meters
20 feet	=	6.10 meters
30 feet	=	9.14 meters
40 feet	=	12.19 meters
50 feet	=	15.24 meters
60 feet	=	18.29 meters
70 feet	=	21.34 meters
80 feet	=	24.39 meters
90 feet	=	27.43 meters
100 feet	=	30.48 meters

15.2 ELECTRICITY CALCULATIONS

WARNING: ELECTRICITY IS DANGEROUS AND CAN KILL.

ELECTRICITY SHOULD ALWAYS BE TREATED WITH RESPECT.

ALL OPERATIONS INVOLVING ELECTRICITY SHOULD BE CARRIED OUT ONLY BY PROPERLY QUALIFIED PERSONNEL.

THE LOGISTICS OF POWER SUPPLIES FOR FILM AND TELEVISION LIGHTING ARE OFTEN COMPLEX AND MUCH CONTROLLED AND INFLUENCED BY NEEDS AND CIRCUMSTANCES OF THE JOB IN HAND. IN ADDITION, THERE ARE ALWAYS LOCAL RULES AND REGULATIONS THAT MUST BE OBSERVED. IN THESE CIRCUMSTANCES, ANY INFORMATION RELATING TO ELECTRICITY, AND TO THE CHOICE OF CABLES IN PARTICULAR, PRODUCED BY THIS MANUAL SHOULD BE TAKEN AS A GUIDE ONLY.

The following is intended only as a practical guide to film and television location lighting working practices. It has no relevance to permanent installations in domestic or industrial premises.

15.2.1 Ohm's law relationships

Electric power is measured in Volts (the Electromotive Force), Watts (Power), Amperes (Current or Intensity) and Ohms (Resistance). Their interrelationship is known as 'Ohm's law'.

Simple Ohm's law may be applied to any DC circuit and to AC circuits where no inductance or capacitance is involved as occurs with HMI and other Metal Halide lamps and with electric motors, etc. Where inductance and/or capacitance are present, and there is a difference between true power and apparent power, a power factor must be applied to compensate.

Power factors must also be applied when a mobile generator is operated in adverse ambient conditions (see Section 15.2.4).

15.2.1.1 DC, and AC without inductance and/or capacitance

$$\text{Amps} = \frac{Watts}{Volts} = \frac{Volts}{Resistance} = \sqrt{\frac{Watts}{Resistance}}$$

or

$$A = W/V = V/R = SQR(W/R)$$

$$\text{Resistance (Ohms)} = \frac{Volts}{Amperes} = \frac{Volts^2}{Watts} = \frac{Watts}{Amperes^2}$$

or

$$R = V/A = V*V/W = W/(A*A)$$

$$\text{Volts} = Amps \times Resistance = \frac{Watts}{Amps} = \sqrt{Watts \times Resistance}$$

or

$$V = A*R = W/A = SQR(W*R)$$

$$\text{Watts} = Volts \times Amps = Amps^2 \times Resistance = \frac{Volts^2}{Resistance}$$

or

$$W = V*A = A*A*R = V*V/R$$

15.2.2 Amps/kVA/kW relationships

The capacity of mobile alternators is often quoted in kVA while the lighting load is usually totalled in kW or Amps. In order to know how many watts of lighting an alternator can power or what capacity alternator is required to power a given load it may be necessary to convert kW or Amps into kVA, or vice versa. (1 kW = 1000 Watts)

15.2.2.1 Amps/kVA/kW, single phase AC with inductance and/or capacitance

$$Amps = \frac{kVA \times 1000}{Volts} \times \sqrt{Power factor} = kW \times \frac{1000}{Volts} \div \sqrt{Power factor}$$

or $$A = kVA*1000/V*SQR(Pf) = kW*1000/V/SQR(Pf)$$

$$kVA = \frac{Volts \times Amps}{1000} \div \sqrt{Power factor} = \frac{kW}{Pf}$$

or $$kVA = A*V/SQR(Pf)/1000 = kW/Pf$$

$$kilo\ Watts = \frac{Amps \times Volts}{1000} \times \sqrt{Power factor} = kVA \times Pf$$

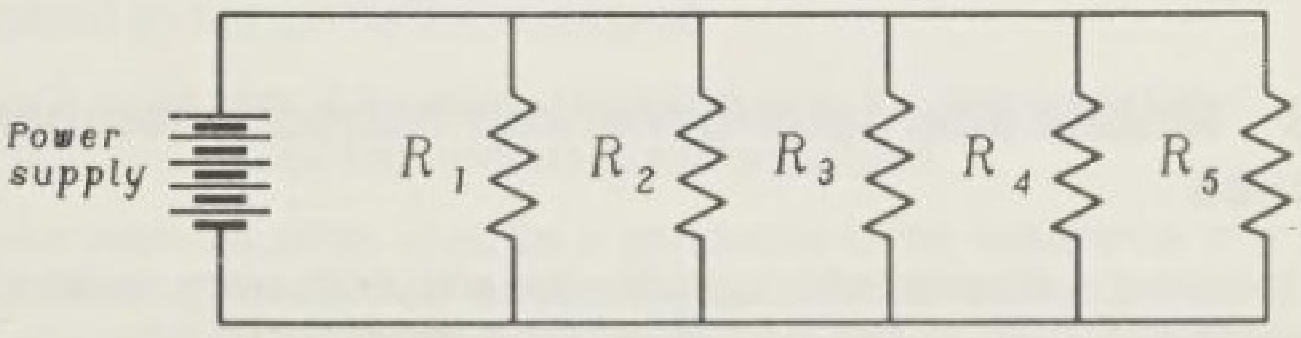
or $$kW = A*V*SQR(Pf)/1000 = kVA*Pf$$

15.2.3 Series and parallel circuits

Lamps and other electric appliances are normally connected in 'Parallel'. This ensures that all units have the same voltage applied but the Amps they draw are accumulative.

Battery cells, on the other hand, are normally connected in 'Series' to form a battery. This ensures that the voltage of individual cells is accumulative but the power output (Amps) remains the same as for a single cell.

15.2.3.1 Parallel circuit



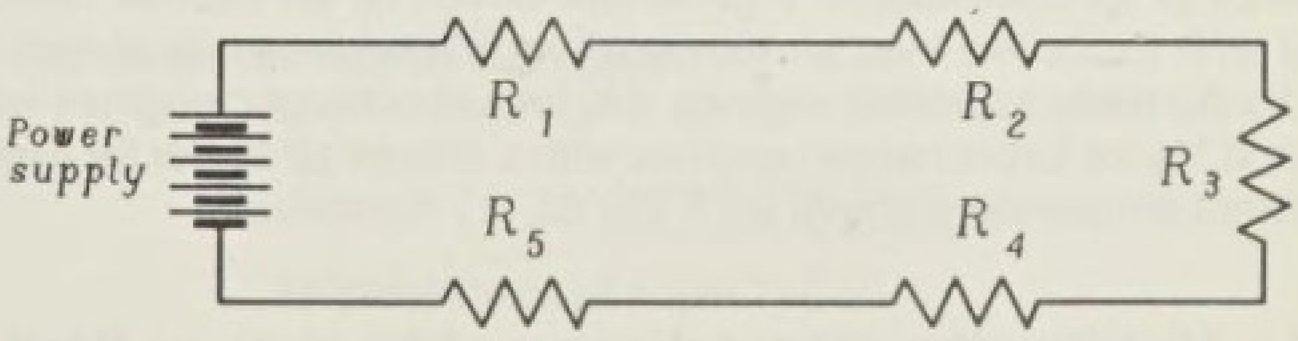
RESISTANCES IN PARALLEL

$$\frac{1}{Total Resistance} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} etc.$$

$$Total\ Amps = A_1 + A_2 + A_3 etc.$$

$$Total\ Volts = V_1 = V_2 = V_3 etc.$$

15.2.3.2 Series circuit



RESISTANCES IN SERIES

$$Total\ Resistance = R_1 + R_2 + R_3 etc.$$

$$Total\ Amps = A_1 = A_2 = A_3 etc.$$

$$Total\ Volts = V_1 + V_2 + V_3 etc.$$

15.2.4 Power rating factors

Many factors conspire to cause electric appliances to draw more power, or for electric cables to carry less power, or for mobile alternators or generators to produce less power, than they are rated so to do. To calculate the end result multipliers, or 'power rating factors', must be applied. Power rating factors are accumulative.

$$\text{Power} = \text{Amps} \times \text{Power rating factor}_1 \times \text{Power rating factor}_2 \text{ .... etc.}$$

15.2.4.1 Metal Halide lighting power rating factors

A multiplier of 1.18 is often applied to the rated wattage of MH lamps (and to AC electric motors) to calculate the power needed to drive them. Alternatively a factor of 0.85 may be applied to the alternator rating to calculate the power available. i.e. to find the needed power that will be required to drive a given load, compared to its rated amperage or wattage, the power rating factor will need to be greater than unity and to find the effective power output of an alternator, compared to its rated power, the power rating factor will be less than unity. See also Section 8.3, Electricity, Power Rating Factors.

15.2.4.2 Mobile alternator/generator altitude power rating factor

The efficiency of an alternator or a generator driven by an internal combustion engine diminishes with altitude. Experience has shown this loss to be 31/2% for every 1000ft (310m) above 500ft (150m) for normally aspirated engines, 21/2% for turbocharged engines (with or without an air cooler).

These factors apply to altitudes up to 8000ft (2500m). Above these altitudes the generator manufacturer should be consulted.

$$\text{Effective generator output} = Amps - \left(\frac{(Altitude - 500)}{1000} \times 3.5 \times \frac{Amps}{100}\right)$$

or

$$\text{Effective generator output} = A - (((Alt - 500)/1000*3.5)*A/100)$$

where A = Amps and Alt = Altitude.

In meters a figure of 155 would be used in place of 500 and 310 in place of 1000.

15.2.4.3 Mobile alternator/generator humidity/temperature % power loss

Derating factors for atmospheric humidity depend both upon relative humidity and atmospheric temperature as per the look-up table in Section 8.3.3.

Care should be taken to use the percentage relative humidity corresponding to the maximum atmospheric under consideration.

It is extremely rare for high relative humidity to be combined with sufficiently high temperature to justify more than a 6% derating.

15.2.4.4 Mobile alternator/generator ambient temperature power rating factor

The efficiency of an alternator or a generator driven by an internal combustion engine diminishes with excessive inlet air temperature. Experience has shown this loss to be about 2% for normally aspirated engines, 3% for turbocharged engines without a charge air cooler and 1% for turbocharged engines with a charge air cooler for every 10°F (5.5°C) rise in ambient temperature above 85°F (30°C).

15.2.4.5 Mobile alternator 'change of frequency (Hz)' power rating factor

The efficiency of an alternator or a generator driven by an internal combustion engine varies with engine speed. Experience has shown that a 60Hz alternator is approximately 15% less efficient at 50Hz and 20% less efficient at 48Hz.

Similarly, a 50Hz alternator is 20% more efficient at 60Hz and 5% less efficient at 48Hz.

15.2.5 Conductor (power cable) calculations

The current-carrying capacity of a conductor is dependent upon many factors including the total cross-sectional area, the material the conductor is made of (usually copper or aluminium), the maximum voltage it may be expected to carry, the type of insulation, the durability of the sheathing and the usage to which the conductor may be put, the maximum permissible operating temperature, whether the conductor is separated from other conductors or if several conductors are bunched together or in a multi-core cable, to local rules and regulations, and so on. For information applying to individual conductors it is necessary to refer to the cable manufacturers and for information regarding safety regulations it is necessary to talk to the local authorities. All such information is outside the scope of this manual.

Note: For the purposes of this manual a 'conductor' refers to a single core of an electric cable. A 'cable' refers to two or more conductors that are required to complete an electric circuit, two in the case of DC or single phase AC (the ground or earth wire is not counted) or, in the case of three phase AC, the number of live conductors plus the neutral conductor.

15.2.5.1 Conductor current density

To compare different cables with different current capacity ratings it is necessary to compare the current densities.

The current density of a cable, e.g. the amount of current (A) which a conductor can safely carry per unit of cross-sectional area, is usually expressed as A/cm^2.

$$\text{Current density} = \frac{Conductor\,safe\,maximum\,load(Amps)}{Conductor\,cross - sectional\,area}$$

15.2.5.2 Conductor resistance and resistivity

The resistance of a conductor (R or Ohms or Ω) is determined by the cross-sectional area, the length of the conductor and the type of material used (resistivity). It is also affected by excessive heat and whether the cables are separated, touching or multicore (see Section 15.2.5.3.3).

The resistance of a conductor is directly proportional to the length. If the length of a conductor is doubled so too will be the resistance.

The resistance of a conductor is *inversely* proportional to the cross-sectional area. If the cross-sectional area is doubled the resistance will be halved.

The resistivity of a material when used as a conductor is the resistance of a standard size unit of that material, measured across opposite faces. In the United States the standard unit is a 'cylinder' 1 mil (1/1000") in diameter and 1 foot long. The International standard is a 1 cm × 1 cm × 1 cm cube.

The resistivity of annealed copper when measured across a circular mil-foot at 20°C (68°F) is 10.37 Ohms. For practical purposes this is usually taken to be 10.4 Ohms. Of aluminium it is 17.0 Ohms.

The resistivity of annealed copper when measured across a one centimeter cube at 20°C is given as $1.7\,\mu\Omega - cm$ (1.7 microhms or 1.7 millionths of an ohm-centimeter). Of aluminum it is $2.845\,\mu\Omega - cm$.

The symbol of resistivity is ρ (the Greek letter *rho*).

The resistance of a conductor can be calculated:

$$\text{Resistance } (\,\Omega\,) = \frac{Resistivity \times Conductor\,length}{Conductor\,cross - sectional\,area}$$

or

$$\text{Resistance } (\,\Omega\,) = (\rho{*}Cl)/Ccsa$$

where ρ = Resistivity, Cl = Conductor length and Ccsa = Conductor cross-sectional area.

Notes: For calculation purposes, all dimensions must be converted to similar measurement systems and units, i.e. feet and circ-mils or centimeters and cm^2.

The length of a conductor includes the outgoing and return. This is twice the 'distance' for single phase or DC current, four times the 'distance' for three phase (the ground or earth wire is not counted).

15.2.5.3 Conductor efficiency losses due to heat

When a current is passed through an aluminium or copper conductor the temperature of that conductor rises and its resistance increases. Extreme examples are the elements of an electric light bulb or an electric fire.

The resistance of a copper conductor increases by 0.004 ohms per ohm per 1°C temperature increase. This is known as the 'temperature coefficient' and written 'α' (the Greek letter *alpha*). The temperature coefficient of aluminium is virtually the same as copper.

Allowance must be made for excessive heat caused by high ambient temperatures, by multicore cables or by touching conductors.

For the following calculations temperatures in °F should first be converted to °C.

15.2.5.3.1 Conductor resistance increase from 0°C

Where the resistance of a particular conductor at 0°C is known:

$$\text{New Resistance (ohms)} = \Omega at 0°C \times (1 + \alpha \times Temperature Rise)$$

or

$$NR\ (\Omega\ ) = R0°C*(1+\alpha*TR)$$

where NR = New resistance (ohms), R0°C = Resistance at O°C, α = temperature coefficient of the conductor and TR = Temperature Rise.

15.2.5.3.2 Conductor resistance increase between two temperatures

Where the resistance of a particular conductor at one temperature is known and it is to be used at another temperature:

$$\text{New Resistance (ohms)} = \frac{Old resistance \times (1 + (\alpha \times New temperature))}{1 + (\alpha \times Old temperature)}$$

or

$$NR\ (\Omega\ ) = (OR*(1+(\alpha*NT)))/(1+(\alpha*OT))$$

where NR = New resistance (ohms), OR = Old Resistance (ohms), α = temperature coefficient of the conductor, NT = New Temperature (°C) and OT = Old Temperature (°C).

15.2.5.3.3 Conductor resistance increase due to touching cables

For rated efficiency single core conductors should be laid at least two cable widths apart, be in freely circulating air conditions and be protected from a hot sun.

A power rating factor must be applied to touching and multicore cables, 0.8 to two core, 0.7 to three core and 0.65 to four core. Other factors apply when there are more than four conductors. The ground (earth) wire is not included in these calculations.

15.2.5.3.4 Efficiency increase due to 3ø operation

Generally speaking, cables and appliances operated with a three phase power supply are more efficient by a factor of $\sqrt{3}$ (approx 1.73).

15.2.6 Conductor size calculations

In North America the size of cable used to distribute AC or DC power is usually referred to by its AWG gage. Alternatively it may be referred to by the diameter expressed as Mils (a whole number of thousandths of an inch), its area in Circular mils or Square mils, its diameter as decimal parts of an inch, or its area as decimal parts of a square inch (in^2). In Europe, and elsewhere in the world, cable size is referred to by its cross-sectional area in mm^2.

15.2.6.1 Conductor cross-sectional area

Calculations involving conductor cross-sectional area require one to know the area of actual copper or aluminium as though the conductor were made of solid metal. However, in the real world of location lighting, solid copper conductors would not be very practical as they could not be bent or coiled easily. To overcome this problem film and television lighting companies use special cables made up of hundreds of fine strands. This enables the cable to be bent round comparatively small radii and handled more easily.

The size of a conductor is often quoted as the number of strands it is made up of together with the AWG size or the diameter (in mils or mm) of each strand. A conductor may be said, for example, to be 1045/30 (1045 strands of 30 AWG wire) or 396/0.40 (396 strands each of 0.40mm diameter). This may be further broken down where cables are made up a number of bundles of strands, in which case they may be quoted as 19 × 44/30, e.g. 19 bundles of 44 strands, each 30 AWG, a total of 836 strands.

15.2.6.2 Conductor size conversions

TABLE 9. CIRC MILS/CM/CM^2/INCHES/IN^2/MILS/INCHES/MM/MM^2 CONVERSIONS

Multiply number of	by	to obtain equivalent number of
Circ mils	0.000,005,068,5	cm^2
Circ Mils	0.000,000,785,4	in^2
Circ Mils	0.000,506,85	mm^2
Circ mils	1.273	Sq mils
ft.	30.48	cm
ft.	0.3048	meters
in.	1000	Mils
in^2	6.4516	cm^2
in^2.	1,273,000	Circ mils
in^2	645.16	mm^2
Mils	0.001	in.
Mils	0.0254	mm
Sq mil	0.7854	Circ mils
cm^2	197297.0307	Circ mils
cm^2	0.155	in^2
cm^2	100	mm^2
mm	39.37	Mils
mm^2	1973.55	Circ mils
mm^2	100	cm^2
mm^2	0.00155	in^2

Notes: A mil is 0.001in.

A Circular mil is the area of a circle having a diameter of 1 mil.

A Square mil is the area of a square 1 mil × 1 mil.

15.2.6.3 AWG sizes

AWG (American Wire Gage) sizes are incremental, the greater the AWG size the smaller the diameter. Sizes larger than 1 are referred to as 0, 00, 000, etc. and usually written 1/0, 2/0, 3/0, etc. Wire gages can run from 50 AWG to 6/0 AWG, the smaller ones being used for strands rather than overall cable sizes.

Conversion between AWG sizes and cross-sectional area or diameter is usually done by look-up tables rather than calculation.

TABLE 10. AWG SIZE CABLE AND RESISTANCE LOOK-UP TABLE

AWG SIZE	Diameter in.	Diameter mils	Area circ. mils	Area in^2	Diameter mm	Area mm^2	Area cm^2	Resistance Ω /1000ft*
40	0.003145	3.1	9.9	0.000008	0.0799	0.005	0.00005	1069.0
39	0.003531	3.5	12.5	0.00001	0.0897	0.0063	0.000063	847.4
38	0.003965	4	15.7	0.000012	0.1007	0.008	0.00008	672.0
37	0.004453	4.5	19.8	0.000016	0.1131	0.01	0.0001	532.9
36	0.005	5	25	0.00002	0.127	0.0127	0.000127	422.6
35	0.005615	5.6	31.5	0.000025	0.1426	0.016	0.00016	335.2
34	0.006305	6.3	39.8	0.000031	0.1601	0.0201	0.000201	265.8
33	0.00708	7.1	50.1	0.000039	0.1798	0.0254	0.000254	210.8
32	0.00795	8	63.2	0.00005	0.2019	0.032	0.00032	167.2
31	0.008928	8.9	79.7	0.000063	0.2268	0.0404	0.000404	132.6
30	0.01003	10	101	0.000079	0.2546	0.051	0.00051	105.1
29	0.01126	11.3	127	0.0001	0.2859	0.064	0.00064	83.37
28	0.01264	12.6	160	0.000126	0.3211	0.081	0.00081	66.11
27	0.0142	14.2	202	0.000158	0.3606	0.102	0.00102	52.43
26	0.01594	15.9	254	0.0002	0.4049	0.129	0.00129	41.58
25	0.0179	17.9	320	0.000252	0.4547	0.162	0.00162	32.97
24	0.0201	20.1	404	0.000317	0.5106	0.205	0.00205	26.15
23	0.02257	22.6	509	0.0004	0.5733	0.258	0.00258	20.74
22	0.02535	25.3	642	0.000505	0.6438	0.326	0.00326	16.45
21	0.02846	28.5	810	0.000636	0.7229	0.41	0.0041	13.04
20	0.03196	32	1020	0.0008	0.8118	0.52	0.0052	10.34
19	0.03589	36	1290	0.00101	0.9116	0.65	0.0065	8.202
18	0.0403	40	1620	0.00128	1.0237	0.82	0.0082	6.505
17	0.04526	45	2050	0.00161	1.1495	1.04	0.0104	5.158
16	0.05082	51	2580	0.00203	1.2908	1.31	0.0131	4.091
15	0.05707	57	3260	0.00256	1.4495	1.65	0.0165	3.244
14	0.06408	64	4110	0.00323	1.6277	2.08	0.0208	2.573
13	0.07196	72	5180	0.00407	1.8278	2.62	0.0262	2.040
12	0.08081	81	6530	0.00513	2.0525	3.31	0.0331	1.618
11	0.09074	91	8230	0.00647	2.3048	4.17	0.0417	1.283
10	0.1019	102	10400	0.0082	2.588	5.3	0.053	1.018
9	0.1144	114	13100	0.0103	2.906	6.6	0.066	0.8070
8	0.1285	128	16500	0.013	3.263	8.4	0.084	0.6400
7	0.1443	144	20800	0.0163	3.665	10.5	0.105	0.5075
6	0.162	162	26200	0.0206	4.115	13.3	0.133	0.4025
5	0.1819	182	33100	0.026	4.621	16.8	0.168	0.3192
4	0.2043	204	41700	0.0328	5.189	21.1	0.211	0.2531
3	0.2294	229	52600	0.0413	5.827	26.7	0.267	0.2007
2	0.2576	258	66400	0.0521	6.543	33.6	0.336	0.1592
1	0.2893	289	83700	0.0657	7.348	42.4	0.424	0.1262
0	0.3248	325	106000	0.0829	8.25	53	0.53	0.1001
00	0.3648	365	133000	0.1045	9.27	67	0.67	0.07939
000	0.4096	410	168000	0.1318	10.4	85	0.85	0.06296
0000	0.46	460	212000	0.1662	11.68	107	1.07	0.04993

* DC resistance of pure copper per 1000ft at 70°F, 20°C

15.2.7 Voltage drop calculations

Due to resistance in a conductor it is inevitable that there will be fewer volts available at the lamp head than at the power input point. Among other things, this will affect the color temperature of the lighting. It is usually considered advisable to limit voltage drop to within 2% of the rated voltage of a bulb. This would mean that a 120V tungsten bulb rated at 3200K would give only 3176K and only 94% of the brightness when run at 117.6V. At 115V the color temperature would only be 3150K and the brightness 87%.

HMI bulbs, on the other hand, give a higher color temperature when the voltage is lower than it should be. See Section 14.5.4.

The thicker and the shorter the cable the less the voltage drop.

Voltage drop is calculated by the very basic Ohm's law function Volts = Amps × Resistance, thus if the Amps load and the Resistance of the cable are known, then the number of volts absorbed can easily be deduced.

Voltage drop is also affected by temperature and conductor proximity (see Sections 8.3.4 and 15.2.5.3).

Cable manufacturers often quote the resistance of their cables as so many Ohms or Ω per 100 or 1000 feet, or as feet per Ohm or Micro-ohm. In Europe and elsewhere it is usually quoted as Ohms per meter or 1000 meters (or per kilometer).

For example, if the resistance of a conductor per 1000 units is known (be they feet or meters) then it is possible to calculate Voltage Drop:

$$\textit{Voltage drop} = \frac{Amps \times Cablelength\,(ft) \times number of conductors \times Ohms\,per\,1000ft.}{1000}$$

or

$$Vd = A*Cl*Cn*R/1000$$

where Vd = Voltage drop, A = Amps, Cl = Cable length (feet or meters), Cn = the number of conductors, R = Resistance (Ohms per unit of length) and 1000 = the unit of cable length.

Where the resistance per unit of cable length is not quoted the voltage drop may be calculated:

$$\textit{Voltage drop} = Amps \times Resistance = \frac{Watts}{Volts} \times Resistance$$

15.2.7.1 Voltage drop %

If the original voltage and the voltage drop are known the voltage drop may be expressed as a percentage:

$$\textit{Voltage drop \%} = \frac{Voltage drop}{Original voltage} \times 100$$

or

$$Vd\,\% = Vd/V_1*100$$

If the original and the terminal voltages are known the resulting voltage drop % may be calculated:

$$\textit{Voltage drop \%} = \frac{(V_1 - V_2)}{V_1} \times 100$$

or

$$(V_1 - V_2)/V_1*100$$

where Vd% = Voltage drop %, V_1 = Original voltage and V_2 = Terminal voltage.

Note: Because the units used for measuring resistivity, cable length and cable cross-sectional area are quite different in America compared to most of the rest of the world, so too are the most practical means of calculating needed cable sizes and voltage drop in the two systems. Section 15.2.7.2 describes calculations commonly used in North America and Section 15.2.7.3 describes calculations used in parts of the world that use the metric system.

15.2.7.2 Calculating voltage drop in American size cables

If the cable length is in feet and the cable size is in Circular Mils (see Section 15.2.6 for conversion from AWG gage and other cross-sectional area standards) a practical estimate of the voltage drop may be calculated by the simple formulae:

$$\text{Voltage drop} = \frac{Amps \times cable\,length(ft) \times number\,of\,conductors \times 22}{Conductor\,cross-sectional\,area(Circular\,mils)}$$

or

$$Vd = A*Cl*Cn*22/Ccsa$$

where Vd = Voltage drop, A = Amps, Cl = Cable length (feet), Cn = number of Conductors, 22 = the factor for copper cable and Ccsa = Cable cross-sectional area in circular mils.

Note: The above factor of 22 applies only to copper conductors and 1ø or DC current (21.6 is slightly more precise). For aluminium conductors the factor is 36.

Example: A 90 Amp load is to be run at the end of a 50ft run of copper cable. The voltage starts out at 120V 1ø AC and the cable size is 1AWG. What will be the voltage drop (approximately), and what will be the % voltage drop? The conductors are separated and the temperature is normal.

Key Sequence	Example	Display
Enter Amps	90	90
Touch multiply	×	90
Enter length of cable (feet)	50	50
Touch multiply	×	4500
Enter number of conductors (out and return)	2	2
Touch multiply	×	9000
Enter factor for copper conductor	22	22
Touch divide	÷	198000
Enter conductor Cross-sectional area (circ mils) (see Section 15.2.6.3)	83700	83700
Touch equals (voltage drop)	=	2.3655914
Touch divide	÷	2.3655924
Enter original voltage	120	120
Touch multiply	×	0.0197133
Enter 100	100	100
Touch equals	=	1.971327

Answer: Conductor cross-sectional area (circ mils) = 83700, voltage drop ≈ 2.4V, % Voltage drop ≈ 1.97%.

Computer input
A*Cl*Cn*22/Ccsa
Let A= 90, Cl = 50, Cn = 2, 22 = the factor for a copper conductor and Ccsa = 83700
90*50*2*22/83700
2.3655914

2.3655914/V*100
Where V = 120 and 100 = the percentage factor
2.3655914/120*100
1.9713262

An even simpler way to make a rough estimate of expected voltage drop is to remember that the resistance of a 1/0 AWG conductor is just over 0.01 Ohms per 100ft and that it doubles for every three AWG sizes smaller (3 AWG) or halves for every three AWG sizes larger (4/0 AWG). With this bit of knowledge it is then possible to divide the conductor length (2 × the cable length for DC or single phase) by 1000 and multiply the answer by the Amps and the Ohms to get a rough idea of what the voltage drop using a given cable for a known load is likely to be. (10 AWG sizes smaller is 10 times the resistance.)

Example: A 200ft cable run is to be used to power a 10 amp load (120V 1ø). What would be the approximate voltage drops for 3 or 6 AWG cables?

1. *The resistance of a 3 AWG cable is twice 0.01 per 100ft = 0.02Ω*
2. *The conductor length of a 200ft cable is 400ft. 400 divided by 100 = 4*
3. *4 × 0.02 = 0.08, times 10 it is 0.8 therefore if a 200ft × 3 AWG cable was used for a 10 Amp load the voltage drop would be approximately 0.8 volts.*
4. *If a 6 AWG cable was used the drop would be double that, 1.6 volts and if it was a 9 AWG cable it would be 3.2 volts.*

Note: To the above should be added a small percentage to allow for the fact that the resistance of copper is a little more than 0.01Ω per 100ft.

15.2.7.2.1 Minimum AWG or Circ. mils size cables for a given % voltage drop

If the load (Amps), the length of the conductor, the conductor material, the supply voltage and the maximum permissible % voltage drop are known the minimum conductor cross-sectional area can be calculated.

Where the cable size is in Circ mils:

$$\textit{Conductor cross-sectional area(Circ mils)} = \frac{Amps \times Conductorlength(ft) \times 22}{Volts \times Voltagedrop\% \div 100}$$

or

$$Ccsa = A*Cl*22/V/Vd\%*100$$

where Ccsa = Conductor cross-sectional area (Circ mils), A = Amps load, Cl = Conductor length (ft), 22* = the factor for a copper conductor, V = Supply voltage and Vd% = Voltage drop as a percentage of the power supply.

* 21.6 is slightly more precise.

Example: A 90 Amp load is to be run at the end of a 50ft run of copper cable. The voltage starts out at 120V 1ø AC and the maximum acceptable Voltage drop = 2%. What is the minimum cable size? The conductors are separated and the temperature is normal.

Key Sequence	Example	Display
Enter Amps	90	90
Touch multiply	×	90
Enter conductor length (2 x 50ft)	100	100
Touch multiply	×	9000
Enter factor for copper	22	22
Touch divide	÷	198000
Enter supply voltage	120	120
Touch divide	÷	1650
Enter Voltage drop %	2	2
Touch multiply	×	825
Enter 100	100	100
Touch equals	=	82500

Answer: Minimum conductor size = 82500 circ mils ≈ 1 AWG

Computer input
A*Cl*22/V/Vd%*100
Let A= 100, Cl = 50, Cn = 2, V = 120 and Vd% = 2
90*50*2*22/120/2*100
82500

15.2.7.2.2 Available voltage, AWG/Circ. mils size cables

Available voltage:

$$\textit{Available voltage} = Volts - \left(\frac{Watts/Volts \times Feet \times 22}{CircularMills} \right)$$

or

$$AV = V - (W/V*ft*22/CM)$$

Example: A 1000W lamp had to be run at the end of a 100ft run of cable. The voltage starts out as 120V DC and the cable size is 14 AWG (4107 CM). What voltage will be available at the lamphead?

Key Sequence	Example	Display
Enter Wattage	1000	1000
Touch divide	÷	1000
Enter volts	120	120
Touch multiply	×	8.3333333
Enter length of conductor (2 x 100 ft)	200	200
Touch multiply	×	1666.6666
Enter constant	22	22
Touch divide	÷	36666.667
Enter cable size (CM) (Table 10)	4107	4107
Touch equals	=	8.9278468
Touch minus	-	8.9278468
Enter original voltage	120	120
Touch equals	=	-111.07215
Convert to a positive number	+/-	111.07215

Answer: Voltage available at lamphead ≈ 111 volts.

Note: This would result in a 120V/3200K tungsten halogen lamp giving a light of only 3110K, a color change of –10 Mireds, and the light output only 77% of normal.

Computer input
V-(W/V*ft*22/CM)
Let V = Volts, W = Watts, ft = feet, 22 = the factor for a copper conductor and CM = Circular mills
120-(1000/120*200*22/4107)
111.0721532

15.2.7.3 Calculating voltage drop in metric size cables

If the cable measurements are in meters and the cable cross-sectional area is in mm^2 the voltage drop can be calculated:

$$\textit{Voltage drop} = \frac{Amps \times Resistivity \times Conductor length(m) \times number of conductors \times 100}{(Conductor cross - sectional area(mm^2) + 100)}$$

or

$$Vd = A*\rho*Cl/100*Cn/(Ccsa/100)$$

where Vd = Voltage drop, A = Amps, ρ = Resistivity of the conductor, Cl = Cable length (meters), Cn = number of Conductors and Ccsa = Cable cross-sectional area (mm^2).

Example: A 100 Amp load is to be run at the end of a 30 meter long copper cable. The voltage starts out at 240V 1ø AC and the proposed cable size is $25mm^2$. What voltage will be available at the lamphead? The conductors are separated and the temperature is normal.

Key Sequence	Example	Display
Enter Amps	100	100
Touch multiply	$\boxed{\times}$	100
Enter resistivity of copper (cm^2)	0.0000017	0.0000017
Touch multiply	$\boxed{\times}$	0.00017
Enter length of cable (meters)	30	30
Touch multiply	$\boxed{\times}$	0.0051
Enter number of conductors (out and return)	2	2
Touch multiply	$\boxed{\times}$	1.02
Convert to centimeters	100	100
Touch divide	$\boxed{\div}$	1.02
Enter conductor Cross-sectional area (mm^2)	25	25
Touch multiply	$\boxed{\times}$	0.0408
Convert to cm^2	100	100
Touch minus	$\boxed{-}$	4.08
Enter original voltage	240	240
Touch equals	$\boxed{=}$	-235.92
Convert to a positive number	$\boxed{+/-}$	235.92

Answer: Voltage available at lamphead ≈ 236 volts.

Computer input
V-(A*ρ*Cl*Cn*100/Ccsa*100)
Let V = 240, A= 100, ρ = 0.0000017, Cl = 30, Cn = 2 and Ccsa = 25
240-(100*0.0000017*30*2*100/25*100)
235.92

The above can be simplified by deleting four noughts from the resistivity factor of copper (making it 0.017) and leaving the conductor length and the cable cross-sectional area in meters and mm^2 respectively. For aluminium the modified resistivity factor would be 0.029.

$$\textit{Voltage drop} = \frac{Amps \times 0.017 \times Conductor length(m) \times number of conductors}{Conductor cross - sectional area(mm^2)}$$

or

$$Vd = A*\rho*Cl*Cn/Ccsa$$

where Vd = Voltage drop, A = Amps, ρ = Resistivity of the conductor, Cl = Cable length (meters), Cn = number of Conductors and Ccsa = Cable cross-sectional area (mm^2).

15.2.7.3.1 Minimum needed cable size (metric size cables)

If the minimum acceptable voltage drop is known, the minimum cable cross-sectional area can be calculated:

$$\textit{Needed cross-sectional area} = \frac{Resistivity \times Conductorlength}{Resistance} = \frac{Restivity \times Conductorlength}{(Volts + Amps)}$$

or

$$CSA = R{*}Cl/R = R{*}Cl/(V/A)$$

15.2.7.3.2 Cable size check (metric size cable)

If the length of a conductor (out and return) is known, together with the material of which it is made it is possible to check its average cross-sectional area by powering a known load at the far end of the cable and measuring the voltage drop between both ends:

$$\textit{Cable size}(cm^2) = \frac{Conductorlength(cm) \times Resistivity(\Omega - cm^2)}{Resistance(\Omega)}$$

or

$$\textit{Conductor size} = \rho{*}Cl/R = \rho{*}Cl/((V_1 - V_2)/A)$$

where ρ = Conductor resistivity, Cl = conductor length (out and return), R = resistance, V_1 = Voltage at input end of cable, V_2 = Voltage at output and A = load.

15.2.7.4 Metric cable sizes, equivalents and resistivity

TABLE 11. METRIC SIZE CABLE AND RESISTANCE LOOK-UP TABLE

Area mm^2	Area cm^2	Diameter mm	Nearest (larger) AWG size	Area circ mils	Area in^2	Diameter in	Diameter mils	Resistance Ohms per 1000 meters
1	0.01	1.13	17	1974	0.0016	0.0445	45	17
1.5	0.015	1.38	15	2960	0.0023	0.0543	54	11.333
2.5	0.025	1.78	13	4934	0.0039	0.0701	70	6.8
4	0.04	2.26	11	7894	0.0062	0.089	89	4.25
6	0.06	2.76	9	11841	0.0093	0.1087	109	2.833
10	0.1	3.57	7	19736	0.0155	0.1406	141	1.7
16	0.16	4.51	5	31577	0.0248	0.1776	178	1.063
25	0.25	5.64	3	49339	0.0388	0.222	222	0.68
35	0.35	6.68	1	69074	0.0543	0.263	263	0.486
50	0.5	7.98	0	98678	0.0775	0.3142	314	0.34
70	0.7	9.44	000	138149	0.1085	0.3717	372	0.243
95	0.95	11	0000	187487	0.1473	0.4331	433	0.179
120	1.2	12.36		236826	0.186	0.4866	487	0.142
150	1.5	13.82		296033	0.2325	0.5441	544	0.113

* Resistance of pure copper at 70°F, 20°C

15.2.8 Total load calculations

When a number of lamps are to be operated from a common power source the combined amperage may be found by totalling the wattage and then dividing it by the voltage:

$$\textit{Amps} = \frac{Watts + watts + watts}{Volts} \text{ or } \textit{Amps} = (W + W + W)/V$$

Where a power factor must be applied the amperage must be calculated:

$$\textit{Amps (MH lighting, etc.)} = \frac{(Watts + watts + watts) \times power\ rating\ factor}{Volts}$$

or

$$\textit{MH Amps} = ((W + W + W){*}Pf)/V$$

where MH = Metal Halide type lighting (HMI, etc.), W = Watts and Pf = Power factor.

15.3 EXPOSURE CALCULATIONS

Seven factors affect exposure. They are: aperture, camera speed, film speed, filter factor, light level, neutral density filtering and shutter angle. In stills photography camera speed and shutter angle are combined into 'exposure time'.

Neither a calculator nor a computer can be used to determine correct exposure but what they can do is to calculate what change should be made to one parameter to compensate for a known change in another.

A typical situation might arise where it is known that f/8 will produce the correct exposure for a camera running at 24 fps but now the camera speed is to be increased to 48 fps. To what aperture should the lens be set to give the same exposure?

To achieve this, two calculations must be made. The first is to determine the amount of change (the change factor), and then to apply that multiplier to the parameter that must be changed as a consequence. In the example above the camera speed would be doubled yet the aperture would need to be changed from f/8 to f/5.6 to compensate.

15.3.1 Exposure change factors

15.3.1.1 Aperture

1. Given the old and new lens apertures (stops), what is the change factor?

$$\text{Change factors} = \left(\frac{Old\,stop}{New\,stop}\right)^2$$

or

$$\text{Change factors} = (OS/NS)^\wedge 2$$

where OS = Old stop and NS = New stop.

Example: The aperture is to be changed from f/8 to f/5.6. What is the Change Factor?

Key Sequence	Example	Display
Enter Old stop	8	8
Touch divide	÷	8
Enter New stop	5.6	5.6
Touch equals	= §	1.4285714
Touch multiply (with a scientific calculator touch keys marked §)	× or x^2 §	1.4285714
Touch equals	=	2.040816327

Answer: The change factor = 2.

Computer input
(OS/NS)^2
Let OS = 8, and NS = 5.6
(8/5.6)^2
2.04081632

2. Given the change factor and an old stop setting, what should be the new setting?

$$\text{New lens aperture} = Old\,stop \times \sqrt{Change\,factor}$$

or

$$\text{Old lens aperture} = OS{*}SQR(CF)$$

where OS = Old stop and CF = Change factor

Example: Some other exposure parameter has been changed and the aperture must be changed to compensate. The Change Factor is 2, the current stop is f/8, what should the new stop be?

Key Sequence	Example	Display
Enter Change factor	2	2
Touch square root	√	1.4142135
Touch multiply	×	1.4142135
Enter Old stop	8	8
Touch equals	=	11.313708

Answer: The new stop ≈ f/11.

Computer input
OS*(SQR(CF))
Let OS = 8 and CF = 2
8*(SQR(2))
11.3137085

15.3.1.2 Camera speed

1. Given the old and the new camera speeds, what is the change factor?

$$\text{Change factor} = \frac{Old fps}{New fps}$$

or

$$\text{Change factor} = Ofps/Nfps$$

where Ofps is the old camera speed and Nfps is the new camera speed.

2. Given the change factor and an old fps setting, what should be the new setting to achieve the same exposure?

$$\text{New fps} = Old fps \times Change factor$$

or

$$\text{New fps} = Ofps * CF$$

15.3.1.3 Exposure time

As already noted, exposure time is a combination of camera speed and shutter angle.

1. Given the old and the new exposure times (seconds), what is the change factor?

$$\text{Change factor} = \frac{New Exposure Time}{Old Exposure Time}$$

or

$$\text{Change factor} = NET/OET$$

Note: The exposure time may be entered either as a fraction (1/1000 sec.) or as a decimal (0.001).

2. Given the change factor and an old exposure time, what should be the exposure time to achieve the same exposure?

$$\text{New exposure time} = Old Exposure Time \div Change factor$$

or

$$\text{New exposure time} = OET/CF$$

15.3.1.4 Film speed

1. Given the old and new film speeds (ASA or EI), what is the change factor?

$$\text{Change factor} = \frac{New\,film\,speed}{Old\,film\,speed}$$

or

$$\text{Change factor} = NEI/OEI$$

where NEI = New Exposure Index and OEI = Old Exposure Index.

2. Given the change factor and an old film speed, what should be the film speed to achieve the same exposure?

$$\text{New film speed} = Old\,film\,speed \times Change\,factor$$

or

$$\text{New film speed} = OEI{*}CF$$

15.3.1.5 Filter factor

1. Given the old and new filter factor, what is the change factor?

Note: No filter = 1, 1 stop = 2, 2 stops = 4, etc.)

$$\text{Change factor} = \frac{Old\,filter\,factor}{New\,filter\,factor}$$

or

$$\text{Change factor} = Off/Nff$$

where Off = Old filter factor and Nff = New filter factor.

2. Given the change factor and an old filter factor, what should the new filter factor be?

$$\text{New filter factor} = \frac{Old\,filter\,factor}{Change\,factor}$$

or

$$\text{New filter factor} = Off/CF$$

15.3.1.6 Light level

1. Given the old and new light levels (Foot candles or Lux), what is the change factor?

$$\text{Change factor} = \frac{New\,light\,level}{Old\,light\,level}$$

or

$$\text{Change factor} = Nll/Oll$$

where Nll = New light level and Oll = old light level.

2. Given the change factor and an old light level, what should be the new light level?

$$\text{New light level} = \frac{Old\,light\,level}{Change\,factor}$$

or

$$\text{New light level} = OEI/CF$$

15.3.1.7 Neutral density filter

1. Given the old and new neutral density filter densities, what is the change factor?

Note: No filter = 0, 1 stop = 0.3, 2 stops = 0.6, etc.

$$\textit{Change factor} = 10^{(Old\,ND\,filter - New\,ND\,filter)}$$

or

$$\textit{Change factor} = 10\text{^}(OND - NND)$$

where OND = Old ND filter density and NND = New ND filter density.

Example: A 0.6ND filter is to be used in place of a 0.3ND. What is the change factor?

Note: A scientific calculator or a computer is necessary for this calculation.

Key Sequence	Example	Display
Enter old ND filter density	0.3	0.3
Touch minus	−	0.3
Enter new ND filter density	0.6	0.6
Touch equals	=	-0.3
Find antilog	INV	-0.3
	LOG	0.5011872

Answer: The change factor ≈ 0.5.

Computer input
10^(OND-NND)
Let OND = .3 and NND = .6
10^(.3-.6)
.5011872336E-01 (0.5)

2. Given the change factor and an old ND filter density, what should be a new ND filter density?

$$\textit{New ND filter density} = \mathrm{Log}^{10}\,Change\,factor + Old\,ND\,filter\,density$$

or

$$\textit{New ND filter density} = \mathrm{LOG}(CF) + OND$$

Example: Some other exposure parameter has been changed and a neutral density filter must be used to compensate. The change factor is 2 and there was no filter in use before. What ND filter should be used?

Note: A scientific calculator or a computer is necessary for this calculation.

Key Sequence	Example	Display
Enter Change factor	2	2
Find log	LOG	0.30103

Answer: A 0.3ND filter is required. Note: As there was no ND filter in use already in this example it was not necessary to add the density of the old ND filter.

Computer input
LOG(CF)+OND
Let CF = 2 and OND = 0
LOG(2)
3.010299957E-01 (0.3)

15.3.1.8 Shutter angle

1. Given the old and new shutter angles, what is the change factor?

$$\text{Change factor} = \frac{\text{New shutter angle}}{\text{Old shutter angle}}$$

or

$$\text{Change factor} = NSA/OSA$$

where NSA = New shutter angle and OSA = old shutter angle.

2. Given the change factor and an old fps setting, what should be the new setting?

$$\text{New shutter angle} = \frac{\text{Old shutter angle}}{\text{Change factor}}$$

or

$$\text{New shutter angle} = OSA/CF$$

15.3.2 Exposure time

Exposure time of a cine camera with a rotating shutter

$$\text{Exposure time (secs.)} = \frac{\text{Shutter angle}}{360} \times \frac{1}{\text{Camera speed}}$$

or

$$\text{Exposure time (secs.)} = SA/360^{*}(1/fps)$$

where SA = Shutter angle and fps = frames per second.

Example: A film camera with a 200° shutter is to run at 32 fps. What is the exposure time?

Key Sequence	Example	Display
Enter shutter angle	200	200
Touch divide	÷	200
Enter 360	360	360
Touch divide	÷	0.5555555
Enter camera speed	32	32
Touch equals	=	0.0173611
Find reciprocal to convert to a fraction	/ or 1/x §	0.0173611
Touch equals	=	57.600036

Answer: The exposure time is 0.01736 seconds or almost 1/60 sec.

Computer input
decimal = SA/360/fps
fraction = 1/(SA/360/fps)
Let SA = 200 and fps = 32
decimal = 200/360/32
fraction = 1/(200/360/32)
1.73611111E-02 (0.01761) or 1/57.6

15.4 FILM LENGTH, TIME & WEIGHT CALCULATIONS

15.4.1 Film running time to length

15.4.1.1 Given running time and feet or meters per minute

$$\mathit{Length} = \mathit{Running\,time}\,(\mathit{mins.}) \times \mathit{feet\,or\,meters\,per}\ \mathrm{min}.$$

Example 1: How many feet long is a 35mm film which runs at 24 fps for 1 hour 30 mins?

Key sequence	Example	Display
Enter time (hrs.)	1	1
Touch multiply	×	1
Enter mins. in 1 hr.	60	60
Touch plus	+	60
Enter time (mins.)	30	30
Touch multiply	×	30
Enter 35mm ft per min. (see table)	90	90
Touch equals	=	8100

Answer: 8100 feet.

Computer input
((hrs*60)+min)*90
Let hr = 1 and min = 30
((1*60)+30)*90
8100

15.4.1.2 Given running time, frames per second and frames per foot or meter

$$\mathit{Length} = \frac{\mathit{running\,time}\,(\mathit{secs.}) \times \mathit{frames\,per\,second}}{\mathit{number\,of\,frames\,per\,ft.\,or\,m.}}$$

or

$$\mathit{Length} = (\mathrm{sec} * \mathit{fps}) / \mathit{fpf}\ \mathrm{or}\ \mathit{fpm}$$

where sec = seconds, fps = frames per second, fpf = frames per foot and fpm = frames per meter.

Example 2: What is the length of a 17 sec. 16mm film insert for PAL TV at 25fps?

Key Sequence	Example	Display
Enter time (secs.)	17	17
Touch multiply	×	17
Enter camera speed (fps.)	25	25
Touch divide	÷	425
Enter 16mm frames per ft. (see table)	40	40
Touch equals	=	10.625

Answer: 10.625 feet of film.

To convert decimal parts of a foot into frames, subtract the whole number of feet from the total and multiply the remainder by the number of frames per foot:

Touch minus	−	10.625
Enter whole feet	10	10
Touch multiply	×	0.625
Enter frames per ft. (see table)	40	40
Touch equals	=	25

Answer: 10 feet 25 frames.

Computer input
sec*fps/fpf
Let sec = 17, fps = 25 and fpf = 40
17*25/40
L = 10.625 feet

followed by

INT(L) and (L-(INT(L)*40
Let L = 10.625
INT(10.625) feet and (10.625-(INT(10.625)))*40 frames
10 feet 25 frames

15.4.2 Film length to running time

15.4.2.1 Given film length and feet or meters per minute

$$\text{Running time (mins.)} = filmlength \times ft.or m.per \text{ min.}$$

Example 3: What is the screening time of 1500ft. of 35mm film at 90ft. per min?

Key Sequence	Example	Display
Enter footage	1500	1500
Touch divide	÷	1500
Enter 35mm feet per minute (see table)	90	90
Touch equals	=	16.666

Answer: 16 2/3 minutes.

15.4.2.2 Given film length, frames per foot or meter and feet or meters per second

$$\text{Running time (sec.)} = \frac{length \times fr.perft.orm.}{cameraspeed(fps.)}$$

or $$\text{Running time (sec.)} = (L*fpform.)/fps.$$

where L = film length, fpf = frames per foot or meter and fps = frames per second.

Example 4: How long will 30ft. of 16mm film run for at 50fps?

Key Sequence	Example	Display
Enter footage	30	30
Touch multiply	×	30
Enter 16mm frames per ft. (see table)	40	40
Touch divide	÷	1200
Enter camera speed (fps.)	50	50
Touch equals	=	24

Answer: 24 seconds.

15.4.3 Blow-up or reduction length

Given original length and original and new film sizes

Blow-up or reduction length = original length × length conversion factor

Example 5: What will be the length of 16mm film when reduced from 580ft of 35mm?

Key Sequence	Example	Display
Enter 35mm film length	580	580
Touch multiply	×	580
Enter length conversion factor (see table)	0.4	0.4
Touch equals	=	232

Answer: The 16mm print will be 232 feet long.

15.4.4 24/25 fps running time conversions

Given original running time

24/25 fps new running time = time × conversion factor

Example 6: A 30 sec commercial shot for NTSC TV at 24 fps. is to be shown on PAL TV at 25 fps. What will be its new running time?

Key Sequence	Example	Display
Enter original time	30 sec	30
Touch multiply	×	30
Enter 24/25 fps. conversion factor (see table)	0.96	0.96
Touch equals	=	28.8

Answer: Just under 29 seconds.

15.4.5 Film length/roll size

15.4.5.1 Roll diameter (ins.) to film length (ft)

$$\text{Film length (ft.)} = \left(\left(\frac{RD}{2}\right)^2 - \left(\frac{CD}{2}\right)^2\right) \times \pi \times TH \div 12$$

or

$$\text{Film length (ft.)} = (((RD/2)\wedge 2) - ((CD/2)\wedge 2))*\Pi/TH/12$$

where RD = Roll diameter (ins.), CD = Core diameter (ins.) and TH = Film thickness (ins.).

Example: A camera assistant has a short end of film of unknown length. In the darkroom he marks the diameter on a piece of paper which he measures later. The diameter is 8 in., the core diameter is 2 in. and the film is 0.006 in. thick.

Key sequence	Example	Display
Clear memory	MC	0
Enter core diameter	2	2
Touch divide	÷	2
Enter 2	2	2
Touch equals §	= §	1§
Touch multiply (to square)	× or x2 §	1
Put into memory	M+	1
Clear screen	C	0
Enter roll diameter	8	8
Touch divide	÷	8
Enter 2	2	2
Touch equals §	= §	4§
Touch multiply (to square)	× or x2 §	4 or 16§
Touch equals	=	16
Touch minus	-	16
Touch memory recall	MR	1
Touch equals §	= §	15§
Touch multiply	×	15
Enter Pi	3.1416 or p §	3.1416
Touch divide	÷	47.124
Enter film thickness	0.006	0.006
Touch divide	÷	7854
Enter 12 (see note below)	12	12
Touch equals	=	654.5

Answer: ≈ 654 ft.

§ Applies only to 'scientific' calculators.

Computer input (ins.)
(((RD/2)^2)–((CD/2)^2))*Π/TH/12
Let RD = 8, CD = 2 and TH = 0.006
(((8/2)^2)–((2/2)^2))*Π/0.006/12
654.4984695

If using metric units, with everything in mm, it would be necessary to change the 12 in the above example to 1000 for the roll length to be in meters, e.g.:

Computer input (mm)
(((RD/2)^2)–((CD/2)^2))*Π/TH/1000

Note: The thickness of film varies slightly depending upon the manufacturer, the base thickness, the emulsion thickness, whether the film is processed or not, and the humidity. The tightness of the winding will also affect the roll size. In the above examples, a film thickness of 0.006 in. (0.1524 mm) has been used. For some filmstocks it could be that 0.005 in (0.127 mm), or even thinner, would be more appropriate. To find a suitable film thickness setting by trial and error use a roll of known diameter and length as a standard.

15.4.5.2 Film length to roll diameter

$$\textit{Roll diameter (ins.)} = \left(\sqrt{\left(\left(RL + \left(\left(\left(\frac{CD}{2}\right)^2\right) \times \Pi \div TH \div 12\right)\right) \times 12 \times TH \div \Pi\right)}\right) \times 2$$

or $$\textit{Roll diameter (ins.)} = (SQR((RL + (((CD/2)\text{^}2)*\Pi/TH/12))*12*TH/\Pi))*2$$

where RL = Roll length (ft), CD = Core diameter (ins) and TH = film thickness (ins).

Example: A 100 minute 35mm film, 9000 ft. long is to be joined into one roll on a 3" dia. core. The film thickness is 0.006 in. What is the diameter of the roll?

Key sequence	Example	Display
Enter core diameter	3	3
Touch divide	÷	3
Enter 2	2	2
Touch equals	=	1.5
Touch multiply (to square)	× or x2§	1.5 or 2.25§
Touch equals	=	2.25
Touch multiply	×	2.25
Enter Pi	3.1416 or p	3.1416
Touch divide	÷	7.0686
Enter film thickness	0.006	0.006
Touch divide	÷	1178.1
Enter 12 (see note below)	12	12
Touch plus	+	98.175
Enter roll length	9000	9000
Touch equals §	=	9098.175
Touch multiply	×	9098.175
Enter 12 (see note below)	12	12
Touch multiply	×	109178.1
Enter film thickness	0.006	.006
Touch divide	÷	655.0686
Enter Pi	3.1416 or p	3.1416
Touch equals	=	208.51432
Touch square root	√	14.440024
Touch multiply	×	14.440024
Enter 2	2	2
Touch equals	=	28.880048

Answer ≈ 29 in.

§ Applies only to 'scientific' calculators.

Computer input (ft. & ins.)
(SQR(RL+(((CD/2)^2)*Π/TH/12))*12*TH/Π))*2
Let RL = 9000, CD = 3 and TH = 0.006
(SQR(9000+(((3/2)^2)*Π/.006/12)*12*.006/Π)*2
28.88008353

If using metric units, with the film length in meters and the film thickness and the core diameter both in mm, it would be necessary to change the 12 in the above example to 1000 for the roll diameter to be in mm., e.g.:

Computer input (m & mm)
(SQR(RL+(((CD/2)^2)*Π/TH/1000))*1000*TH/Π))*2

15.4.6 SFX speeds

15.4.6.1 Speeded up or slowed down action: needed camera speed

When a camera is run faster than the projector, the action will appear to be slowed down when seen on the screen and conversely, if the camera is run at a slower frame rate than the projector, action on the screen will appear to be speeded up. Time can be compressed or expanded.

If the time the action takes, or the camera running time (the event time), and the projector frame rate (usually 24 fps) are known then the needed camera frame rate is:

$$\text{Camera frames per second} = screentime \times projectorfps \div eventtime$$

or

$$Cfps = ST*Pfps/ET$$

where Cfps is the camera frames per second, ST is the screen time, Pfps is the projector speed and ET is the event time.

Both the event time and the screen time must be entered in seconds:

$$\text{Time} = (Hours \times 3600) + (Minutes \times 60) + Seconds$$

If the result is less than 1 fps then the reciprocal will be the number of seconds between exposures.

Example 1: An event taking 2 seconds in real time is to take 7 seconds when it appears on the screen at 24 fps. What should be the camera speed?

Key sequence	Example	Display
Enter screen time	7	7
Touch multiply	×	7
Enter projector fps	24	24
Touch divide	÷	168
Enter event time	2	2
Touch equals	=	84

Answer: The camera must be run at 84 fps.

Example 2: A flower in bloom must be filmed over a period of four days and appear on the screen for 1 minute. What should be the interval between exposures?

Key sequence	Example	Display
Enter screen time (secs)	60	60
Touch multiply	×	60
Enter projector fps	24	24
Touch divide	÷	1440
Enter event time (days)	4	4
Touch divide	/	360
Convert days to hours	24	24
Touch multiply	×	15
Convert hours to seconds	3600	3600
Touch divide (to find the reciprocal)	÷	0.0041666
Touch equals	=	240.00384

Answer: Interval between exposures ≈ 240 seconds (4 minutes).

Computer input
1/(ST*Pfps/ET)
Let ST = 60, Pfps = 24, ET = (4*24*3600)
1/(60*25/(4*24*3600))
240

15.4.6.2 Needed number of frames

The needed number of frames to occupy a given period of screen time is:

$$\textit{Number of frames} = \textit{Screen time (secs)} \times \textit{projector fps}$$

15.4.6.3 Miniatures

When filming miniatures it is necessary to speed-up the camera to scale gravity proportionally to the scale of the model:

$$\textit{Camera frames per second} = \sqrt{\frac{\textit{size of the original}}{\textit{size of the miniature}}} \times \textit{projector speed}$$

or

$$Cfps = SQR(SO/SM)*Pfps$$

where Cfps is the camera frames per second, SO is the full size of the original, SM is the size of the miniature and Pfps is the projector frame rate.

Note: This calculation is the basis for tests and does not work if there is any water in the scene.

Example: A miniature explosion is to be filmed. The model is 10 feet wide and represents a building and street 60 feet wide. At what speed should the camera be run?

Key sequence	Example	Display
Enter size of the original	60	60
Touch divide	÷	60
Enter size of the miniature	10	10
Touch equals	=	6
Touch square root	√	2.4494897
Touch multiply	×	2.4494897
Enter projector frame rate	24	24
Touch equals	=	58.787754

Answer: Recommended camera speed = 60 fps.

Computer input
SQR(SO/SM)*Pfps
Let SO=60, SM=10 and Pfps=24
SQR(60/10)*24
58.78775383

15.4.6.4 Pan speed

As is well known, if a camera is panned too fast the vertical elements within the scene (fences and posts, particularly) will appear to strobe. The precise fastest permissible panning speed is dependent not only on the speed of the pan but also on the direction of the pan in relation to the direction of the shutter and the focal length of the lens in relation to the image size. There are no practical hard and fast rules but experienced camera operators can usually judge what is safe by the length of time it takes for a static object to pass from one side of the screen to the other. As a starting point 4 seconds for a spherical lens (any focal length) and 7 seconds for anamorphic is usually safe. As with depth of field, fine tuning is best done by looking at dailies critically.

Once the safe maximum panning speed at 24fps has been established the maximum safe panning at any other frame rate can be calculated:

$$\textit{Max. safe across frame pan time} = \textit{Known time} \div \textit{new fps} \times \textit{normal fps}$$

or

$$NPT = KPT/Nfps*Kfps$$

where NPT = New pan time, KPT = Known pan time, Nfps = New camera frame rate and Kfps = Known frame rate.

15.4.6.5 Screen speeds

Any modification to the camera frame rate compared to the projector frame rate will cause an apparent change to the speeds of all objects within the picture.

15.4.6.5.1 Resulting apparent object speed

If the true speed of an object is known the apparent (on-screen) object speed can be calculated:

$$\textit{Screen object speed} = \mathit{True\,speed} \times \frac{\mathit{Projector\,fps}}{\mathit{Camera\,fps}}$$

or

$$SS = TS*Pfps/Cfps$$

where SS = Screen object speed, TS = True speed, Pfps = Projector frame rate and Cfps = Camera frame rate.

15.4.6.5.2 Needed true object speed

If an object needs to look as though it is travelling at a certain speed on the screen and a modified camera frame rate is already known, the true speed at which the object must travel can be calculated:

$$\textit{True object speed} = \mathit{Screen\,speed} \times \frac{\mathit{projector\,fps}}{\mathit{camera\,fps}}$$

or

$$TS = SS*Cfps/Pfps$$

where TS = True speed, SS = Screen object speed, Cfps = Camera frame rate and Pfps = Projector frame rate.

15.4.6.5.3 Needed camera speed

If the true speed of an object is known and the wish is to make it look as though it is travelling on the screen at a known different speed then the change of camera frame rate to make that come about can be calculated:

$$\textit{Modified camera frames per second} = \mathit{Projector\,fps} \times \frac{\mathit{True\,speed}}{\mathit{Screen\,speed}}$$

or

$$Cfps = Pfps*TS/SS$$

where Cfps= Camera frame rate, Pfps = Projector frame rate, TS = True object speed and SS = Screen speed.

15.4.6.6 Screen time

If a scene or event is shot with a modified camera frame rate, the time it will take to show the action on the screen can be calculated:

$$\textit{Screen time} = \mathit{Event\,time} \times \frac{\mathit{Camera\,fps}}{\mathit{Projector\,fps}}$$

or

$$ST = ET*Cfps/Pfps$$

where ST = Screen time, ET = Event time, Cfps = Camera frame rate and Pfps = projector frame rate.

The screen time and the event time can be hours, minutes or seconds so long as they are both the same. If the camera frame rate is less than 1 frame per second its interval between exposures (in seconds) must be entered as a reciprocal i.e. one exposure every ten seconds should be entered 1/10.

15.4.7 Film calculation factors

15.4.7.1 Film feet

TABLE 12. FILM FEET PER MINUTE

FILM GAGE AND PERFS PER FRAME	FEET PER MINUTE 24fps	25fps	30fps
65/70mm × 5	112.5		140.62
35mm × 8	180		
35mm × 4	90	93.75	112.5
35mm × 3	67.5	70.31	84.38
35mm × 2	45		
16mm	36	37.5	45
Super 8	20		

TABLE 13. FRAMES PER FOOT

FILM GAGE AND PERFS PER FRAME	FRAMES PER FOOT
65/70mm × 5	12.8
35mm × 8	8
35mm × 4	16
35mm × 3	21.33
35mm × 2	32
16mm	40
Super 8	72

15.4.7.2 Film meters

TABLE 14. FILM METERS PER MINUTE

FILM GAGE AND PERFS PER FRAME	METERS PER MINUTE 24fps	25fps	30fps
65/70mm × 5	34.29		42.86
35mm × 8	54.86		
35mm × 4	27.43	28.59	34.29
35mm × 3	20.57	21.43	25.72
35mm × 2	13.72		
16mm	10.97	11.43	13.72
Super 8	6.1		

TABLE 15. FRAMES PER METER

FILM GAGE AND PERFS PER FRAME	FRAMES PER METER
65/70mm × 5	42
35mm × 8	26.25
35mm × 4	52.5
35mm × 3	70
35mm × 2	105
16mm	131.23
Super 8	236.21

15.4.7.3 Blow-up and reduction conversion factors

TABLE 16. FILM GAGE TO FILM GAGE CONVERSION FACTORS

65/70mm	to or from	35mm × 4 perf	1.25
35mm × 8 perf		35mm × 4 perf	0.5
35mm × 4 perf		65/70mm	0.8
35mm × 4 perf		35mm × 3 perf	1.33
35mm × 4 perf		35mm × 2 perf	2
35mm × 4 perf		16mm	2.5
35mm × 4 perf		Super 8	4.5
35mm × 3 perf		35mm × 4 perf	0.75
35mm × 3 perf		16mm	1.87
16mm		35mm × 4 perf	0.4
16mm		Super 8	1.8

15.4.7.4 Film running time conversion factors

TABLE 17. FPS TO FPS CONVERSION FACTORS

24 fps	to or from	25 fps	0.96
24 fps		30 fps	1.25
30 fps		29.97 fps	1.001001

15.4.7.5 Film thicknesses

TABLE 18. FILM BASE THICKNESSES

MANUFACTURER	TRIACETATE in	TRIACETATE mm	POLYESTAR in	POLYESTAR mm
Agfa		0.152		0.137
Eastman	0.006		0.005	
Fuji		0.145 – 0.155		0.130 – 0.135

15.5 LIGHTING CALCULATIONS

15.5.1 Metal Halide lighting safe operating windows

When filming by Metal Halide, and other discontinuous light sources, which have two peaks of light for every AC power cycle, it is necessary to ensure that the speed of the camera (fps), the frequency of the power supply (Hz) and the exposure time (a combination of camera speed (fps) and shutter angle (SA°)) are compatible.

If the frequency of the lighting power is fixed (as from a mains supply or a crystal controlled alternator) then either the camera speed must be exactly divisible into twice the frequency of the power supply Hz × 2 or the exposure period must be exactly equal to the time duration between two or more peaks of light.

Notes: Shutter angle is always referred to as though it was a single bladed shutter even though it be a twin bladed shutter with an opening only half of what it is known as.

In all the following conditions absolute accuracy of setting is vital.

15.5.1.1 MH *safest* camera speeds given power frequency (Hz)

The safest, simplest, easiest and most widely used method of ensuring flicker-free cinematography is to run the camera at a speed (fps) which is *exactly* divisible into twice the frequency (the number of light peaks per second) provided that both the frequency and the camera speed are exact. This usually means running the lighting off a mains power supply and controlling the camera speed either by crystal control or by slaving it to the lighting power supply. Under these circumstances *any* shutter angle is allowable.

In a 60Hz environment possible camera speeds are 10, 12, 15, 20, 30 and 60 fps. In a 50 Hz environment the speeds are 12.5, 25 and 50 fps, with 16.33 and 33.66 fps recurring as possible speeds if you could set the camera speed accurately enough.

Other possible speeds are 120 fps with 60 Hz and 100 fps with 50 Hz if the camera can be synchronized to have the shutter open only at the moment of peak lighting. In this case very little image would be seen through a spinning mirror reflex camera viewfinder.

See graph in Section 14.5.4.

15.5.1.2 MH safe camera speed given power frequency and shutter angle

Most cameras have shutters of known opening and based on this it is possible to select safe flicker-free operating windows by adjusting the camera speed (especially when it is crystal controlled for accuracy) and selecting the number of lighting peaks per exposure period (normally two but can be any number for low frame rates).

1. Safe camera speeds with **60** Hz lighting:

$$\textit{Camera speed (fps)} = shutterangle \div 3 \div LPEP$$

2. Safe camera speeds with **50** Hz lighting:

$$\textit{Camera speed (fps)} = shutterangle \div 3.6 \div LPEP$$

where LPEP = Light peaks per exposure period.

15.5.1.3 MH safe shutter angle given power frequency and camera speed

Cameras which have shutters which can be set accurately to any opening, and have motors which can be set to run at precise camera speeds, can be operated with MH lighting over a wide range of frame rates by adjusting the shutter angle to suit the camera speed.

1. Safe shutter angle with **60** Hz lighting:

$$\text{Shutter angle}^{\circ} = camera\,speed \times 3 \times LPEP$$

2. Safe shutter angle with **50** Hz lighting:

$$\text{Shutter angle}^{\circ} = camera\,speed \times 3.6 \times LPEP$$

15.5.1.4 MH safe frequency given camera speed and shutter angle

Finally, it is also possible to find safe MH flicker-free operating windows to suit a particular camera speed/shutter opening by adjusting the frequency of the lighting power supply.

This is most likely to be done by adjusting the operating speed of a mobile alternator which should either have a crystal controlled governor or the camera should be synchronized with a power supply. Using this method 50 Hz alternators are often run at a reduced speed to create a 48 Hz power supply which can be used safely with a 24 fps camera.

$$\text{Supply frequency (Hz)} = camera\,speed \times 360 \div shutter\,angle$$

15.5.2 Light coverage

The usable spread of light from a fresnel (focusable) lamp is taken to be from the point either side of the center of the beam where the intensity of the light falls to half that of the center. The beam angle is from the half peak intensity points back to the lamp.

The easiest method of measuring the performance of a lamp is to shine it at a plain white surface and to note the beam width from the point on one side where the intensity is half that of the center intensity to a similar point on the other side. Note also the distance from the lamp to the white surface and the center beam light intensity. From this information it is possible to calculate the beam width and light intensity at other distances.

The following calculations are only at all meaningful at distances at least 20 times the width of the front of the lamp. They require the use of a scientific calculator with trigonometrical functions. If a computer is used it must be set to operate in degrees (not radians or grads).

15.5.2.1 Beam angle° given beam width and distance

If many calculations involving the spread of light of various luminaries are to be made, it is as well to compile a list of all the beam angles of the various types of lamps at full spot and full flood.

$$\text{Beam angle}^{\circ} = \mathrm{Tan}^{1}\frac{Beamwidth}{2Distance} \times 2$$

or

$$BA^{\circ} = ATN(BW/2/D)*2$$

where BA° = Beam angle°, BW = Beam width and D = Distance.

Example: The spread of light from a lamp at 15ft distance is 8ft across. What is the Beam angle?

Key Sequence	Example	Display
Enter Beam width	8	8
Touch divide	/	8
Enter 2	2	2
Touch divide	/	4
Enter distance	15	15
Touch equals	=	0.2666667
Touch Tan^{-1}	Tan-1	14.931417
Touch multiply	x	14.931417
Enter 2	2	2
Touch equals	=	29.862834

Answer: ≈ 30°.

Computer input
ATN(BW/2/D)*2
Let BW = 8 and D = 15
ATN(8/2/15)*2
29.86283436

15.5.2.2 Beam width given beam angle° and distance

This equation is used to calculate the light spread of a particular lamp at various distances.

$$\text{Beam width} = Distance \times \mathrm{Tan}\left(\frac{Beamangle^{\circ}}{2}\right) \times 2$$

or

$$BW = D * \mathrm{TAN}(BA^{\circ}/2)*2$$

where BW = Beam width, D = Distance and BA° = Beam angle°.

Example: A lamp with a 30° beam angle must be set at a distance of 15ft to the subject. What will be the Beam width?

Key Sequence	Example	Display
Enter Beam angle°	30	30
Touch divide	÷	30
Enter 2	2	2
Touch equals	=	15
Touch Tan	Tan	0.2679492
Touch multiply	x	0.2679492
Enter distance	15	15
Touch multiply	x	4.0192379
Enter 2	2	2
Touch equals	=	8.0384758

Answer: ≈ 8ft.

Computer input
D*TAN(BA°/2)*2
Let BA = 30 and D = 15
15*TAN(30/2)*2
8.038475773

15.5.2.3 Distance given beam width and beam angle°

This equation is used to calculate the distance at which a lamp of known beam angle must be set in order to achieve a particular spread of light.

$$Distance = \frac{Beamwidth}{2} \div \mathrm{Tan}\frac{Beamangle^\circ}{2}$$

or

$$D = (BW/2)/(\mathrm{TAN}(BA^\circ/2))$$

where D = Distance, BW = Beam width and BA° = Beam angle°.

Example: It is known that at full flood a particular lamp has a beam angle of 30°. It is required to cover an area 8ft across. How far away must it be set?

Key Sequence	Example	Display
Enter Beam angle°	30	30
Touch divide	÷	30
Enter 2	2	2
Touch equals	=	15
Touch Tan	Tan	0.2679492
Put into memory	M+	0.2679492
Clear screen	C	0
Enter Beam width	8	8
Touch divide	÷	8
Enter 2	2	2
Touch divide	÷	4
Recall memory	RM	0.2679492
Touch equals	=	14.928203

Answer: ≈ 15ft.

Computer input
(BW/2)/(TAN(BA°/2))
Let BW = 8 and BA = 30
(8/2)/(TAN(30/2))
14.92820323

15.5.3 Scene illumination

If the Peak Beam Intensity (Candelas) of a particular lamp (and at a particular flood/spot setting, if applicable) is known for a particular distance the level of illumination at any other distance may be calculated.

Because the light intensity of various luminaires varies so greatly, even between two units which are identical in all but age, it is advisable to measure the Peak Beam Intensity of individual units at a known distance (which should be at least 20 times the width of the front of the widest lamp to be used) and to keep a library of lamp performances.

If working in feet the brightness level will be in foot candles, and vice versa. If metric measurements are used then the calculations will be in meters and lux.

15.5.3.1 Peak beam intensity given scene illumination and distance

$$\text{Peak beam intensity} = Scene\ illumination \times Distance^2$$

or

$$PBI = SI*D*D$$

where PBI = Peak beam intensity, SI = Scene illumination and D = Distance.

Example: Measured at a distance of 30ft, the illumination level at the center of a beam of light is found to be 50 foot candles. What is the Peak beam intensity?

Key Sequence	Example	Display
Enter illumination level (fc)	50	50
Touch multiply	⊠	50
Enter distance (ft)	30	30
Touch multiply	⊠	1500
Enter distance (ft)	30	30
Touch equals	⊜	45000

Answer: ≈ 45,000.

Computer input
SI*D*D
Let SI = 50 and D = 30
SI*30*30
45000

15.5.3.2 Scene illumination given peak beam intensity and distance

$$\text{Scene illumination} = \frac{\text{Peakbeam Intensity}}{\text{Distance}^2}$$

or

$$SI = PBI/D/D$$

where SI = Scene illumination, PBI = Peak beam intensity and D = Distance.

Example: Having been measured at a distance of 30ft, a lamp is found to have the Peak beam intensity of 45,000. It is now to be used at 15ft. How many foot candles can be expected at the center of the beam?

Key Sequence	Example	Display
Enter lamp Peak beam intensity	45000	45000
Touch divide	÷	45000
Enter distance (ft)	15	15
Touch divide	÷	3000
Enter distance (ft)	15	15
Touch equals	=	200

Answer: = 200.

Computer input
PBI/D/D
Let PBI = 45000 and D = 15
45000/15/15
200

15.5.3.3 Comparative scene illumination

If the level of illumination from a lamp at one particular distance is known, the level at a new distance can be calculated:

$$NLL = OLL*OD*OD/ND/ND$$

where NLL = New light level, OLL = Old light level, OD = Old distance and ND = New distance.

Example: It is known that at 30ft the level of illumination from a particular lamp is 100 foot candles. What will be the illumination level at 20ft?

Computer input
OLL*OD*OD/ND/ND
Let OLL = 100, OD = 30 and ND = 20
100*30*30/20/20
225

15.6 OPTICAL CALCULATIONS

The optical calculations contained in this section are only those that a practical cinematographer or camera assistant applies to every-day cinematography, even if he uses a book of look-up tables to do so. It does not set out to be a section on the theory of lens design.

15.6.1 Lens calculations

15.6.1.1 Lens focal length/image size/object distance/object size

There is often a requirement to show what size of image can be covered by a given focal length on a certain size film, how far back the camera will need to be to cover a certain area with a certain focal length lens or what focal length lens will be required to take or project a picture of a certain width from a certain distance.

An approximation of all of these problems may be calculated by the following formula:

1. $\frac{Object size(O)}{Image size(I)} = \frac{Distance(D)}{Lens Focal Length(f)}$

or $(O/I) = (D/f)$

where I = the camera or projector Image size, O = the Object or picture size, D = the Distance and f = the Lens focal length.

If any three factors are known the other can be calculated, viz:

1. $Object\ or\ picture\ size = \frac{Distance \times Image size}{Focal length}$

or $O = (D*I)/f$

2. $Distance = \frac{Object or picture size \times Focal length}{Image size}$

or $D = (O*f)/I$

3. $Focal\ length = \frac{Distance \times Image size}{Object size}$

or $f = (D*I)/O$

4. $Image\ size = \frac{Distance \times Focal length}{Object size}$

or $I = (D*f)/O$

where Object or image size is the width or height of the photographed object or projected picture and the Image size is the same dimension, i.e. if the Object size is the Object width then the Image size must be the Image width.

See tables at the end of this section for standard image sizes.

15.6.1.2 Anamorphic calculations

When making width of object calculations for anamorphic cinematography, where the horizontal angle of coverage is twice the normal, it is necessary either to multiply the object (picture) width by two or to halve the lens focal length (f). The picture height remains the same, viz:

1. $Anamorphic\ picture\ width = \frac{Distance \times Image width \times 2}{Focal length}$

or $AO = (D*I*2)/f$

where AO = the Anamorphic Object or picture width, D = Distance, I = the camera or projector Image width and f = Lens focal length.

2. $Anamorphic\ lens\ focal\ length = \frac{Distance \times Image width \div 2}{Object size}$

or $Af = (D*I/2)/O$

where Af = Anamorphic lens focal length.

3. $$\text{Anamorphic picture height} = \frac{\text{Distance} \times \text{Imageheight}}{\text{Focallength}}$$

or $$AH = (D*I)/f$$

where AH = Anamorphic object or picture height.

15.6.1.3 Aspect ratio

The aspect ratio of the picture or image area is the width divided by the height:

1. $$\text{Aspect ratio} = \frac{\text{Picturewidth}}{\text{Pictureheight}}$$

or $$AR = PW/PH$$

2. $$\text{Picture height} = \frac{\text{Pictureheight}}{\text{Aspectratio}}$$

or $$PH = PW/AR$$

where AR = Aspect ratio, PW = Picture width and PH = Picture height.

15.6.1.4 Mixed measurement lens calculations

Lens calculations may be all one type of measurement, i.e inches or meters, etc., or may be mixed providing the lens focal length and image (aperture) sizes are both expressed in millimeters and the Object or picture size are both in either feet or meters. The answer will be in feet or meters respectively, viz:

1. $$\frac{\text{Objectsize (ft.)}}{\text{Imagesize (mm)}} = \frac{\text{Distance (ft.)}}{\text{Lens focal length (mm)}}$$

or $$Oft/Imm = Dft/fmm$$

If any three factors are known the other can be calculated, viz:

2. $$\text{Object or picture width (ft)} = \frac{\text{Distance (ft)} \times \text{Image (mm) size}}{\text{Lens focal length (mm)}}$$

or $$Oft = (Dft*Imm)/fmm$$

3. $$\text{Distance} = \frac{\text{Objectorpicturesize (ft)} \times \text{Focallength (mm)}}{\text{Imagesize (mm)}}$$

or $$Dft = (Oft*fmm)/Imm$$

4. $$\text{Focal length(mm)} = \frac{\text{Distance (ft)} \times \text{Imagesize (mm)}}{\text{Objectsize (ft)}}$$

or $$\text{Focal length(mm)} = \frac{\text{Distance (m)} \times \text{Imagesize (mm)}}{\text{Objectsize (m)}}$$

where Oft = the Object or picture size in feet, Imm = the Image size in mm, D = the Distance in feet and fmm = the lens focal length in mm.

15.6.1.5 Distance: given picture width and lens focal length

Note: All the following calculations are correct for 'thin lenses' and will not necessarily be accurate for multi-element lenses, especially at very close distances.

Example: A set 15ft wide is to be photographed on a 35mm Academy frame with a 40mm lens and must fill the screen. How far back must the camera be?

Key Sequence	Example	Display
Enter picture width (ft)	15	15
Touch multiply	×	15
Enter Lens focal length (mm)	40	40
Touch divide	÷	600
Enter 35mm Academy image width (mm) (table 15)	21.11	21.11
Touch equals	=	28.422549

Answer: ≈ 28.4 feet, or just over 28 feet 5 inches (see tables).

Computer input
0*f/I
Let O = 15, f = 40 and I = 21.11
15*40/21.11
28.4225456

Note: This is to the 'entrance pupil' of the lens and for most practical applications more distance may need to be allowed to accommodate the rest of the lens, the camera, the dolly and the crew, etc..

15.6.1.6 Distance: given picture width and anamorphic lens focal length

Example: If the above example was an anamorphic picture the calculation would be:

Key Sequence	Example	Display
Enter picture width (ft)	15	15
Touch multiply	×	15
Enter lens focal length (mm)	40	40
Touch divide	÷	600
Enter anamorphic squeeze ratio	2	2
Touch divide	÷	300
Enter 35mm anamorphic image width (mm) (table 15)	21.29	21.29
Touch equals	=	14.091123

Answer: = 14.09 feet. or a little under 14 feet 2 inches (see above).

Computer input
0*f/ASR/I
Let O = 15, f = 40, ASR = 2 and I = 21.11
15*40/2/21.11
14.21127428

15.6.1.7 Focal length: given distance and picture width

Example: What focal length lens is necessary on a 16mm projector to fill a screen 8ft. wide with a throw of 35ft.?

Key Sequence	Example	Display
Enter distance	35	35
Touch multiply	×	35
Enter 16mm aperture width (ins) (table 15)	0.380	.380
Touch divide	÷	13.3
Enter screen width	8	8
Touch equals	=	1.6625
Touch multiply	×	1.6625
Enter 25.4 to convert to mm	25.5	25.4
Touch equals	=	42.2275

Answer: 1.6625 inches or just over 42 mm.

Computer input
D*I/O*25.4
Let D = 35ft, I = 0.380in, O = 8ft and 25.5 = in/mm conversion
35*0.380/8*25.4
42.2275

15.6.1.8 Lens focal length to lens angle

In the film world it is most usual to express 'lens angle' by the focal length of the lens whereas in television it is defined as the horizontal angle covered by a lens when focused at infinity. It sometimes happens, therefore, that a director or a cameraman used to working in one medium is at a loss when asked for, say, a 45° shot on a 35mm film camera or an 11mm lens on a television camera when, in reality, they are the same thing.

Calculations involving angles must be done using a scientific type calculator and with the trig. functions set for 'degrees'.

Many computers and spreadsheets (particularly) operate not in degrees of angle but in 'radians' and for the benefit of users of such equipment the computer type formulae is listed a second time incorporating *57.2958 or *0.0174533 to convert to radians or degrees as necessary. On pocket computers the function for Tan^{-1} is ATN and on spreadsheets it is @ATAN.

$$\textit{Lens angle}^\circ = 2\tan^{-1}\left(\frac{\textit{Image width}}{\textit{Focal length} \times 2}\right)$$

or

$$L^\circ = (ATN(I/(f*2)))*2$$

or where the computer operates only in radians,

$$L^\circ = (ATN(I/(f*2)))*2*57.2958$$

where L° Lens angle(degrees), I = Image width, f = Lens focal length.

Example: What is the horizontal angle of a 25mm lens on a 35mm film camera?

Key Sequence	Example	Display
Enter Image width (mm) (Table 16)	21.11	21.11
Touch divide	÷	21.11
Touch 2	2	2
Touch divide	÷	10.555
Enter lens focal length	25	25
Touch equals	=	.4222
Find inverse tangent	tan-1	22.889471
Touch multiply	×	22.889471
Enter 2	2	2
Touch equals	=	45.778942

Answer: ≈ 45°.

Computer input
If the computer operates in degrees: (ATN(I/(f*2)))*2
If the computer operates in radians: (ATN(I/(f*2)))*2*57.2958
Let I = 21.11 and f = 25
(ATN(21.11/(25*2)))*2
45.7789421

15.6.1.9 Lens angle to focal length

$$\textit{Focal length} = \frac{\textit{Image width}}{2\tan(\textit{lens angle}^\circ \div 2)}$$

or

$$f = I/(2*(\mathrm{TAN}(L^\circ/2)))$$

or where the computer operates only in radians:

$$f = I/(2*(\mathrm{TAN}(L^\circ*0.0174533/2)))$$

where f = Lens focal length(mm), I = Image width, L° = Lens angle.

Example: What focal length(mm) is a 30° lens on a 16mm camera?

Key Sequence	Example	Display
Enter lens angle(°)	30	30
Touch divide	÷	30
Touch 2	2	2
Touch equals	=	15
Find tangent	tan	0.2679491
Touch multiply	×	0.2679491
Enter 2	2	2
Touch equals	=	0.5358983
Find reciprocal	1/x	1.866025
Touch multiply	×	1.866025
Enter Image width(mm) (Table 16)	9.65	9.65
Touch equals	=	18.007145

Answer: ≈ 18 mm.

Computer input
If computer operates in degrees: I/(2*(TAN(L°/2)))
If computer operates in radians: I/(2*(TAN(L°*0.0174533/2)))
Let I = 9.65 and L° = 30
9.65/((TAN(30/2))*2
18.00714515

15.6.1.10 Lens angle and distance to scene or picture width

$$\textit{Picture width} = 2 \times \textit{Distance} \times \tan\frac{\textit{lensangle}^\circ}{2}$$

or

$$PW = (\mathrm{TAN}(L^\circ/2))*D*2$$

or where the computer operates only in radians:

$$PW = (\mathrm{TAN}(L^\circ*0.0174533/2))*D*2$$

where PW = Picture width, D = Distance and L° = Lens angle.

Example: A TV camera with a 30° lens is 40ft from a background? What width is covered?

Key Sequence	Example	Display
Enter lens angle(°)	30	30
Touch divide	÷	30
Enter 2	2	2
Touch equals	=	15
Find tangent	tan	0.2679491
Touch multiply	×	0.2679491
Enter distance	40	40
Touch multiply	×	10.717968
Enter 2	2	2
Touch equals	=	21.435935

Answer: ≈ 21.4ft, or about 21 ft. 5in. (Table 4).

Computer input
If computer operates in degrees: (TAN(L°/2))*D*2
If computer operates in radians: (TAN(L°*0,0174533/2))*D*2
Let L° = 30 and D = 40
(TAN(30/2))*40*2
21.43593539

15.6.1.11 Object width and distance to lens angle

$$\textit{Lens angle(degrees)} = 2\tan^{-1}\left(\frac{objectwidth}{2}\right) \div Distance$$

or

$$L^{\circ} = (ATN(O/2/D))*2$$

or where the computer operates only in radians:

$$L^{\circ} = (ATN(O/2/D))*2*57.2958$$

where L° = Lens angle(degrees), O = Object width and D = Distance.

Example: What angle lens is necessary to take in an object 20ft wide from a distance of 30ft.?

Key Sequence	Example	Display
Enter Object width	20	20
Touch divide	÷	20
Enter 2	2	2
Touch divide	÷	10
Enter Distance	30	30
Touch equals	=	0.3333333
Find inverse tangent	tan-1	18.434949
Touch multiply	x	18.434949
Enter 2	2	2
Touch equals	=	36.869898

Answer: ≈ 37°.

Computer input
If computer operates in degrees: (ATN(O/2/D))*2
If computer operates in radians: (ATN(O/2/D))*2*57.2958
Let O = 20 and D = 30
(ATN(20/2/30))*2
36.86989765

15.6.1.12 Lens angle and object width to distance

$$\textit{Distance} = \left(\frac{Objectwidth}{2}\right) \div \tan\left(\frac{Lensangle}{2}\right)$$

or

$$D = (O/2)/(\mathrm{TAN}(L^{\circ}/2))$$

or where the computer operates only in radians:

$$D = (O/2)/(\mathrm{TAN}(L^{\circ}*0.174533/2))$$

where D = Distance, O = Object width and L° = Lens angle.

Example: How far back is it necessary to be to include an 80ft wide scene with a 60° lens?

Key Sequence	Example	Display
Clear memory	MC	0
Clear screen	C	0
Enter lens angle(°)	60	60
Touch divide	÷	60
Enter 2	2	2
Touch equals	=	30
Find tangent	tan	0.5773502
Enter into memory	M+	0.5773502
Clear screen	C	0
Enter picture width	80	80
Touch divide	÷	80
Enter 2	2	2
Touch divide	÷	40
Recall memory	MR	0.5773502
Touch equals	=	69.282032

Answer: = 70 ft.

Computer Input
If computer operates in degrees: (O/2)/(TAN(L°/2))
If computer operates in radians: (O/2)/(TAN(L°*0.174533/2))
Let O = 80 and L° = 60
(80/2)/(TAN(60*0.174533/2))
69.2820323

15.6.2 Camera and projector aperture dimensions

The image sizes listed on the following two pages are derived as follows:

Camera apertures, except those marked *, all conform to ANSI, BSI and ISO published standards.

The TV 'transmitted' and 'safe' sizes are American Recommended Practices and often differ from usage elsewhere in the world.

Apertures marked * are not published standards but are 'custom and practice of the trade'. I am obliged to Panavision Inc. for supplying the hard mask and finder marking dimensions.

Although the projection apertures are laid down standards there can be no guarantee that this is what ends up on the screen of a local theatre. One of the problems is that film projectors when new are often supplied with undersized masks so that the installation engineer can file out sufficient around the edges to eliminate the keystone effect of projectors mounted high above the audience and to make square the images from two projectors converging on one screen. Neither can there be any guarantee that the moveable masks around the screen conform to standards or even that the projector operator will get the racking correct unless the film was shot with a camera fitted with a widescreen hard mask or the print was printed that way.

15.6.2.1 Table 19. Motion picture camera apertures

CAMERA APERTURES

65mm

	inches	mm
Width	2.066	52.50
Height	0.906	23.00

65mm 15 PERF IMAX/OMNIMAX

inches	mm
2.799	71.09
2.072	52.63

VISTAVISION*

	Inches	mm
Width	1.485	37.72
Height	0.991	25.17

35mm FULL APERTURE

	inches	mm
Width	0.980	24.92
Height	0.735	18.67

35mm ANAMORPHIC

inches	mm
0.864	21.95
0.732	18.60

35mm ACADEMY

inches	mm
0.864	21.95
0.630	16.00

35mm 1.66:1*

	inches	mm
Width	0.864	21.95
Height	0.520	13.22

35mm 1.75:1*

inches	mm
0.864	21.95
0.494	12.54

35mm 1.85:1*

inches	mm
0.864	21.95
0.467	11.86

3 PERFORATION*

	inches	mm
Width	0.868	22.05
Height	0.546	13.97

2 PERFORATION (TECHNISCOPE)*

inches	mm
0.864	21.95
0.366	9.30

16mm STANDARD

	inches	mm
Width	0.404	10.26
Height	0.295	7.49

----------16mm type W (Super 16)----------			
16mm CAMERA APERTURE		35mm DUPLICATE NEGATIVE	
inches	mm	inches	mm
0.493	12.52	0.864	21.95
0.292	7.42	0.517	13.13

SUPER 8

	inches	mm
Width	0.224	5.69
Height	0.160	4.22

REGULAR 8

inches	mm
0.193	4.90
0.142	3.60

* Non-standardized camera hard mask sizes.

15.6.2.2 Table 20. Motion picture projector apertures

CAMERA FINDER MARKINGS and PROJECTOR APERTURES

70mm

	inches	mm
Width	1.913	48.59
Height	0.870	22.10

35mm ANAMORPHIC CAMERA MARKING for 70mm PRINT

inches	mm
0.735	19.13
0.668	16.97

35mm FULL FRAME

	inches	mm
Width	0.945	24.00
Height	0.709	18.00

35mm ANAMORPHIC

inches	mm
0.838	21.29
0.700	17.78

35mm ACADEMY

inches	mm
0.825	20.96
0.602	15.29

35mm 1.66:1

	inches	mm
Width	0.825	20.96
Height	0.497	12.62

35mm 1.75:1

inches	mm
0.825	20.96
0.471	11.96

35mm 1.85:1

inches	mm
0.825	20.96
0.446	11.33

35mm TV PROJECTION

	inches	mm
Width	0.816	20.73
Height	0.612	15.54

TV TRANSMITTED

inches	mm
0.792	20.12
0.594	15.09

TV SAFE ACTION

inches	mm
0.713	18.11
0.535	13.59

16:9 for HDTV

inches	mm

SUPER 35 for 2.35:1 ANAMORPHIC

	inches	mm
Width	0.945	24.00
Height	0.394	10.00

SUPER 35 for 2.2:1 70mm

inches	mm
0.945	24.00
0.430	10.92

SUPER 35 for 1.85:1 SPHERICAL

inches	mm
0.945	24.00
0.511	12.98

Note: All the above SUPER 35 formats can have a common headroom

3 PERF 1.85:1 PROJECTION

	inches	mm
Width	0.825	20.96
Height	0.511	12.98

3 PERF TV TRANSMITTED

inches	mm
0.680	17.27
0.511	12.98

3 PERF 1.78:1 HDTF

inches	mm
0.825	20.96
0.464	11.79

16mm STANDARD

	inches	mm
Width	0.378	9.60
Height	0.276	7.01

----------16mm TYPE W (SUPER 16)----------

1.66:1 35mm BLOW-UP

inches	mm
0.463	11.76
0.279	7.09

1.85:1 35mm BLOW-UP

inches	mm
0.463	11.76
0.251	6.38

16mm TV PROJECTION

	inches	mm
Width	0.380	9.65
Height	0.286	7.24

TV TRANSMITTED

inches	mm
0.368	9.35
0.276	7.01

TV SAFE ACTION

inches	mm
0.331	8.41
0.248	6.30

16:9 for HDTV

inches	mm

SUPER 8

	inches	mm
Width	0.215	5.46
Height	0.158	4.01

REGULAR 8

inches	mm
0.179	4.55
0.134	3.40

15.6.2.3 Table 21. Still camera apertures

24 × 36mm

	inches	mm
Width	1.34	34.2
Height	0.90	22.9

SUPERSLIDES

inches	mm
1.5	38.1
1.5	38.1

6 × 6cm

inches	mm
2.03	51.6
2.03	51.6

6 × 9cm

	inches	mm
Width	2.03	51.562
Height	3.04	77.47

inches	mm

inches	mm

15.6.2.4 Table 22. Video camera apertures

Note: The following are approximations only and vary from make of camera to make of camera.

11/4 inch/31.75mm

	inches	mm
Width	0.667	16.33
Height	0.5	12.7

1 inch/25mm

inches	mm
0.5	12.7
0.375	9.52

2/3 inch/18mm

inches	mm
0.346	8.8
0.26	6.6

1/2 inch/12.7 mm

	inches	mm
Width	0.252	6.4
Height	0.189	4.8

15.6.2.5 Table 23. Aspect ratios

FORMAT	ASPECT RATIO	VERTICAL FACTOR
65/70mm	2.2:1	0.45
35mm Anamorphic	2.35:1	0.43
VistaVision	1.5:1	0.67
35mm Full frame	1.33:1	0.75
35mm Academy	1.37:1	0.73
35mm Wide screen	1.66:1	0.60
35mm Wide screen	1.85:1	0.54
35mm TV transmitted	1.33:1	0.75
Super 16	1.69:1	0.59
Regular 16	1.33:1	0.75
16mm TV transmitted	1.33:1	0.75
Super 8	1.76:1	0.57
Regular 8	1.32:1	0.76
TV	1.33:1	0.75
TV 16:9	1.78:1	0.56

15.6.3 Depth of field

The calculation of depth of field is a well-defined mathematical procedure, whereas the assessment of what is acceptably sharp and what is not is a matter of personal judgement.

As already noted in Section 13.3, the subjective assessment of depth of field will depend upon the image format, the type of presentation, the lighting, and not least, the degree of sharpness of the most in-focus part of the scene, by comparison with which anything less than critically sharp will be judged. For this reason, lenses which are particularly sharp and contrasty will appear to have less depth of field than others which are not really sharp anywhere.

When viewing film for critical focus assessment it is as well to remember that pictures projected by a Maltese cross type projector suffer a marked loss of definition in the horizontal plane and that it is better to judge focus by vertical lines, where possible. If checking the focus of a test chart it is preferable to use a microscope or a slide projector rather than a cinema type projector.

15.6.3.1 Circles of confusion

Put simply, the 'Circle of Confusion' is the measure of permissible out-of-focusness.

The choice of the most acceptable C. of C. will depend upon many things and first time users are advised to select a more restrictive setting, say 1/1000" (0.025mm), or smaller, and then to view their results critically until it is possible to decide which C. of C. is suitable for a particular set of conditions.

Generally speaking, the sharper and crisper the lens and the more contrasty the lighting, the smaller the C. of C. that must be selected. With poor quality lenses, or when using diffusion or fog filters, or when photographing in a smoky or hazy atmosphere, it is possible to use a larger C. of C.

There is no rule for specifying any particular maximum circle of confusion except that there is no point in working to a smaller circle than the lens, the effect filtering (if any), the camera filmstock, the printing process and the projection system can resolve.

The final test must always be what is and what is not acceptable on the screen.

Way back in the 1920s and 1930s, when tables of depth of field calculations were first published, Circles of Confusion of 1/500 and 1/1000in. were considered to be adequate, depending more, it would seem, on the gage of film in use rather than the appearance on the screen.

TABLE 24. TRADITIONAL CIRCLES OF CONFUSION

65/70mm	1/500in	0.002in	0.05mm
35mm	1/500in	0.002in	0.05mm
16mm	1/1000in	0.001in	0.025mm

Since then, lens, filmstock, printing and projection technologies have made great advances and what may have been acceptable 50 or more years ago may not be adequate now.

For a scene shot with an old lens, with soft lighting, with diffusion and/or fog filters and/or smoke in the atmosphere, etc., a C. of C. of 1/500in, or even more, may still be adequate.

However, for a scene shot on modern high definition, high contrast lenses which have low veiling glare characteristics, with modern fine grain filmstocks, with contrasty lighting, no filtration and a need for a 'hard look', then to work to a C. of C. of 1/2000in, or less, may be the order of the day.

15.6.3.2 Hyperfocal distance

The hyperfocal distance is the distance at which a lens must be focused for a point at infinity to be recorded by the maximum circle of confusion. It makes use of the maximum depth of field to make an object close to the camera as 'in focus' as is acceptable for an object at infinity.

It is always required when making any Depth of Field or Focus Split calculation.

1.

$$\text{Hyperfocal distance} = \frac{focal\,length \times focal\,length}{circle\,of\,confusion \times lens\,aperture}$$

or

$$H = (f*f)/(cc*S)$$

2. Where the lens focal length is in mm and the circle of confusion is in inches, the hyperfocal distance in feet can be calculated:

$$\text{Hyperfocal distance} = \frac{focal\,length(mm) \times focal\,length(mm) \times 0.000129}{circle\,of\,confusion(\epsilon) \times lens\,aperture(f)}$$

or

$$H = (fmm*fmm*0.000129)/(ccin*S)$$

3. Where the lens focal length and the circle of confusion are in mm, the hyperfocal distance in meters can be calculated:

$$\text{Hperfocal distance} = \frac{focal\,length(mm) \times focal\,length(mm) \times 0.001}{circle\,of\,confusion(mm) \times lens\,aperture(S)}$$

or

$$H = (fmm*fmm*0.001)/(ccmm*S)$$

where H = Hyperfocal distance, f or fmm = Lens focal length, cc or ccin = Circle of confusion and S = Lens aperture.

The Hyperfocal Distance tables in Section 13.3.3 show hyperfocal distances for five different circles of confusion and for a range of lens focal lengths from 10 to 250mm.

If the focus of a lens is set at the hyperfocal distance everything will be acceptably sharp from infinity to half the hyperfocal distance, i.e., in the case above, to 20 ft.

Over the years, many equations for calculating depth of field have been devised. Some older ones are not really relevant to modern lenses.

15.6.3.3 Simple depth of field equations

The most basic depth of field equation, which should only be used for comparatively simple lenses, at medium to long distances and at relatively small apertures, is:

1.

$$\text{Near distance} = \frac{Hyperfocal\,distance \times Focus\,distance}{Hyperfocal\,distance + Focus\,distance}$$

$$\text{Far distance} = \frac{Hyperfocal\,distance \times Focus\,distance}{Hyperfocal\,distance - Focus\,distance}$$

or

$$nD = (H \times F)/(H + F)$$

$$fD = (H \times F)/(H - F)$$

where nD = Near distance, fD = Far distance, H = Hyperfocal distance and F = Focus distance.

Note: This simple formula is only suitable for small fixed focal length lenses where the lens focal length is small compared to the point of focus distance.

Example: Find the near and far depth of field distances of a small 50mm fixed focal length lens focused on 10 ft at f/4 with a circle of confusion of 1/500.

Near distance:

Key Sequence	Example	Display
Enter Hyperfocal distance (Table 23)	40	40
Touch plus	+	40
Enter Focus distance	10	10
Find the reciprocal (with a scientific	÷ or =§	50
calculator use the keys marked §)	= or 1/x§	0.02
Touch multiply	x	0.02
Enter Hyperfocal distance	40	40
Touch multiply	x	0.8
Enter Focus distance	10	10
Touch equals	=	8

Far distance:

Key Sequence	Example	Display
Enter Hyperfocal distance (Table 23)	40	40
Touch minus	-	40
Enter Focus distance	10	10
Find the reciprocal (with a scientific	÷ or =§	30
calculator use the keys marked §)	= or 1/x§	0.0333333
Touch multiply	x	0.0333333
Enter Hyperfocal distance	40	40
Touch multiply	x	1.333332
Enter Focus distance	10	10
Touch equals	=	13.33332

Note: Far distances which are an infinite distance away (infinity) calculate as negative numbers.

Answers: Near distance = 8ft., far distance ≈ 13.3ft. (13ft. 4in., Table 4.)

Near distance:

Computer input
(H×F)/(H+F
Let H = 40 (Table 23) and F = 10
(40×10)/(40+10)
8

Far distance:

Computer input
(H×F)/(H–F)
Let H = 40 (Table 23) and F = 10
(40×10)/(40–10)
13.3333333

Answers: Near distance = 8 ft., far distance ≈ 13.3ft (13 ft. 4 in.)

15.6.3.4 Depth of field with nodal position compensation

With high-performance fixed focal length lenses, especially designed for cinematography, and with large zoom lenses of the types used on professional film cameras, account must be taken of the distance of the front nodal point to the film plane in order to be able to predict Depth of Field with a reasonable amount of precision.

This is because these lenses are physically long compared to their focal length and because depth of field calculations are relative to the position of the front nodal point rather than the focal plane from where cinematographers measure focus distances.

In 1974, W.B. Pollard and the author noted that depth of field calculations made with then available cine calculators and published depth of field tables did not always correspond with depth of field tables supplied by the lens manufacturers, especially those for the Cook Varotal zoom lenses.

As a result, a new formula, taking a compromise front nodal point position into consideration, was devised and incorporated into the Samcine Mk. II CINE CALCULATOR. It has since been used for the Panavision CINEMATOGRAPHERS' COMPUTER CALCULATOR, the dSam CINE CALCULATOR and is used for all the Depth of Field tables in this manual. (For more information see the *Journal of SMPTE*, Volume 84, April 1975, pages 261 - 267.)

The new equations incorporated a 'Fixed Nodal Constant' factor to compensate for the physical length of the lens and the position of the front nodal point:

$$\text{Near distance} = \frac{Hyperfocaldist. \times (Focusdist. - Fixednodalconstant)}{Hyperfocaldist. + Focusdist. - Fixednodalconstant} + Fixednodalconstant$$

$$\text{Far distance} = \frac{Hyperfocaldist. \times (Focusdist. - Fixednodalconstant)}{Hyperfocaldist. - Focusdist. + Fixednodalconstant} + Fixednodalconstant$$

or

$$nD = ((H*(F - FNC))/(H + F - FNC)) + FNC$$

$$fD = ((H*(F - FNC))/(H - F + FNC)) + FNC$$

where nD = Near distance, fD = Far distance, H = Hyperfocal distance, F = Focus distance and FNC = Fixed nodal constant.

Example: Find the near and far depth of field distances of a large 50mm fixed focal length lens focused on 15 ft at f/4 with a circle of confusion of 1/500.

Near distance:

Key Sequence	Example	Display
Clear Memory	MC MC	0
Clear screen	C	0
Enter Hyperfocal distance (Table 23)	40	40
Touch plus	+	40
Enter Focus distance	10	10
Touch minus	−	50
Enter Fixed nodal constant (Table 22)	.16	.16
Put into memory	M+	49.84
Clear screen	C	0
Enter Focus distance	10	10
Touch minus	−	10
Enter Fixed nodal constant	.16	.16
Touch multiply	×	9.84
Enter Hyperfocal distance	40	40
Touch divide	÷	393.6
Recall memory	MR	49.84
Touch plus	+	7.8972712
Enter Fixed nodal constant	.16	.16
Touch equals	=	8.0572712

Far distance:

Key Sequence	Example	Display
Clear Memory	MC MC	0
Enter Hyperfocal distance (Table 23)	40	40
Touch minus	-	40
Enter Focus distance	10	10
Touch plus	+	30
Enter Fixed nodal constant (Table 22)	.16	.16
Put into memory	M+	30.16
Clear screen	C	0
Enter Focus distance	10	10
Touch minus	-	10
Enter Fixed nodal constant	.16	.16
Touch multiply	x	9.84
Enter Hyperfocal distance	40	40
Touch divide	÷	393.6
Recall memory	MR	30.16
Touch plus	+	13.050397
Enter Fixed nodal constant	.16	.16
Touch equals	=	13.210397

Note: Far distances which are an infinite distance away (infinity) calculate as negative numbers.

Answer: Near distance = 8 ft. 1 in., far distance = 13 ft. 2 in.

For a 35mm type zoom lens, with a Fixed nodal constant of 0.66 ft. the answers would be 13.497573 ft (13 ft. 6 in.) and 8.2319497 (8 ft. 3 in), respectively.

Far distance:

Computer input
((H*(F–FNC))/(H–F–FNC))+FNC
Let H = 40 (Table 18), F = 10 and FNC = .16 (Table 22)
((40*(10–.16))/(40–10–.16))+.16
13.35034853

Near distance:

Computer input
((H*(F–FNC))/(H+F–FNC))+FNC
Let H = 40 (Table 18), F = 10 and FNC = .16 (Table 22)
((40*(10–.16))/(40+10–.16))+.16
8.057271268

Answer: Far distance = 13 ft. 4 in., near distance = 8 ft. 1 in.

For a 35mm type zoom lens, with a Fixed nodal constant (FNC) of 0.66ft. the answers would be 13.39346967 ft (13ft. 5in.) and 8.231949737 (8ft. 3in), respectively.

15.6.4 Focus splits

In the real world of cinematography Depth of Field questions are usually asked the other way round. The more likely situation is the need to know the focus setting to hold near and far objects in equal and/or acceptable focus (reverse depth of field).

Other questions that may be asked are 'given the lens focal length, what is the minimum aperture to hold a particular split, or, given the aperture, what is the maximum focal length?'

Further questions are 'Given the lens focal length and aperture and knowing the furthest object that must be held in acceptable focus, what is the nearest distance, or given the near distance, what is the farthest distance?'

15.6.4.1 Equal focus

When two objects at different distances are to be reproduced with maximum, and equal, sharpness, the distance at which the lens should be focused is known as the split focus distance.

This is most easily found by visually setting the focus midway between the two distances engraved on the focus scale, or it may be calculated:

$$\textit{Focus distance} = \frac{2 \times Neardist. \times Fardist.}{Neardist. + Fardist.} + Fixednodalconst.$$

or

$$D = ((2*nD*fD)/(nD+fD)) + FNC$$

where D = Focus distance, nD = Near distance, fD = Far distance and FNC = Fixed nodal constant

Example: Two objects have to be held in equal focus. One is 13ft. from the camera, the other is 8 ft. At what distance should the focus be set?

Key Sequence	Example	Display
Enter Near distance	8	8
Touch plus	+	8
Enter Far distance	13	13
Find reciprocal (with a scientific	÷ or =§	21
calculator use the keys marked §)	= or 1/x§	0.047619
Touch multiply	×	0.047619
Enter 2	2	2
Touch multiply	×	0.095238
Enter Near distance	8	8
Touch multiply	×	0.761904
Enter Far distance	13	13
Touch plus	+	9.904752
Enter Fixed Nodal Constant (see table)**	.16	.16
Touch equals	=	10.064752

** The addition of the Fixed nodal constant may be omitted for quick, round figure, calculations.

Answer: Focus distance ≈ 10 ft.

Computer input
((2*nD*fD)/(nD+fD))+FNC
Let nD = 8, fD = 13 and FNC = .16 (Table 22)
((2*8*13)/(8+13))+.16
10.0647619

15.6.4.2 Minimum aperture

Given the near and far distances, the lens focal length, the Fixed nodal constant and the maximum permissible circle of confusion the question may be asked 'what is the minimum aperture necessary to hold such a split in acceptable focus?'

$$\text{Minimum aperture} = \frac{Focallength^2 \times (Fardistance - Neardistance)}{2 \times C.ofc. \times Fardist. \times Neardist.}$$

or

$$mS = ((f*f)*(fD - nD))/(2*cc*fD*nD)$$

where mS = Minimum aperture, f = lens focal length, fD = Far distance, nD = Near distance and cc = Circle of confusion. All measurements to be in the same denomination, i.e., feet or meters.

Example: Two objects have to be held in equal focus. One is 13 ft. from the camera, the other is 8 ft. Given that it is a large 50mm fixed focal length lens focused on 15 ft. and the maximum acceptable circle of confusion is 1/500 in. What is the minimum aperture?

Key Sequence	Example	Display
Clear memory	MC MC	0
Enter Near distance	8	8
Touch multiply	x	8
Enter Far distance	13	13
Touch multiply	x	104
Enter Circle of confusion	.000166	0.000166
Touch multiply	x	0.017264
Enter 2	2	2
Find reciprocal (if using a scientific	/ or = §	0.034528
calculator use the keys marked §)	= or 1/x §	28.962001
Enter into memory	M+	28.962001
Clear screen	C	0
Enter Far distance	13	13
Touch minus	-	13
Enter Near distance	8	8
Touch multiply	x	5
Recall memory	MR	28.962001
Clear memory	MC	28.962001
Enter into memory	M+	144.81
Clear screen	C	0
Enter Lens focal length (ft, see table)	.164	0.164
Find square (if using a scientific	x or = §	0.164
calculator use the keys marked §)	= or	0.026896
Touch multiply	x	0.026896
Recall memory	MR	144.81
Touch =	=	3.8948097

Answer: Aperture ≈ f/4.

Computer input
((f*f)*(fD-nD))/(2*cc*fD*nD)
Let f = 0.164 (Table 15), fD = 13, nD = 8 and cc = (.002/12).
((.164*.164)*(13-8))/(2*(.002/12)*13*8)
3.879230769

For greater precision, particularly with large zoom lenses, the following equation is preferable:

$$mS = ((f*f)*(fD - nD))/(2*cc*(fD - FNC)*(nD - FNC))$$

where mS = Minimum aperture, f = lens focal length, fD = Far distance, nD = Near distance, C = Circle of confusion and FNC = Fixed nodal constant. All measurements to be in the same denomination, i.e., feet or meters.

Computer input
((f*f)*(fD-nD))/(2*cc*(fD-FNC)*(nD-FNC))
Let f=0.164 (Table 20), fD=13, nD=8, cc = (.002/12) and FNC=0.16 (Table 16)
((.164*.164)*(13-8))/(2*(.002/12)*(13-.16)*(8-.16))
3.910272316

15.6.4.3 Maximum focal length

Given the near and far distances, the lens aperture and the maximum permissible circle of confusion, the question may be asked 'what is the maximum focal length with which it is possible to hold such a split in acceptable focus?'

$$\textit{Maximum focal length} = \sqrt{\frac{2 \times C.ofC. \times Stop \times Fardist. \times Neardist.}{Fardist - Neardist}} \times 304.8$$

or

$$Mf = SQR((2*cc*S*fD*nD)/(fD - nD))*304.8$$

where Mf = Maximum focal length, cc = Circle of confusion, S = Lens aperture (Stop), fD = Far distance and nD = Near distance. All measurements to be in the same denomination, i.e., feet or meters. If in feet multiply the result by 304.8 (as above) and if in meters multiply by 1000 to convert to millimeters.

Example: Two objects have to be held in equal focus. One is 13 ft. from the camera, the other is 8 ft. Given that the lens is operating at f/4 and that the maximum acceptable circle of confusion is 1/500 in (0.002/12 ft.), what is the longest possible lens focal length?

Let cc = .000166 (Table 14), S = 4, fD = 13 and nD = 8 (If the entries are in feet multiply by 304.8 to convert to mm).

Key Sequence	Example	Display
Enter Far distance	13	13
Touch minus	−	13
Enter Near distance	8	8
Find reciprocal (if using a scientific	÷ or =§	5
calculator use the keys marked §	= or 1/x§	0.2
Touch multiply	x	0.2
Enter Near distance	8	8
Touch multiply	x	1.6
Enter Far distance	13	20.8
Touch multiply	x	20.8
Enter stop	4	4
Touch multiply	x	83.2
Enter Circle of confusion (Table 20)	.000166	0.000166
Touch multiply	x	0.0138112
Enter 2	2	2
Touch equals	=	0.0276224
Find square root	√	0.1661998
Touch multiply	x	0.1661998
Enter feet/mm conversion factor	304.8	304.8
Touch equals	=	50.657699

Answer: Focal length ≈ 50mm.

Computer input
SQR((2*cc*S*fD*nD)/(fD–nD))*304.8
Let cc = (.002/12), S = 4, fD = 13 and nD = 8.
SQR((2*(.002/12)*4*13*8)/(13–8))*304.8
50.75934373

For greater precision, particularly with large zoom lenses, the following equation is preferable:

$$Mf = SQR((2*cc*S*(fD - FNC)*(nD - FNC))/(fD - nD))*304.8$$

where Mf = Maximum focal length, cc = Circle of confusion, S = Lens aperture (Stop), fD = Far distance, FNC = Fixed nodal constant and nD = Near distance. All measurements to be in the same denomination, i.e., feet or meters. If in feet multiply the result by 304.8 and if in meters multiply by 1000 to convert to millimeters.

Computer input
SQR((2*cc*S*(fD–FNC)*(nD–FNC)/(fD–nD))*304.8
Let cc = (.002/12), S = 4, FNC = .16, fD = 13, and nD = 8.
SQR((2*(.002/12)*4*(13–.16)*(8–.16))/(13–8))*304.8
49.9390035

Answer: Maximum focal length ≈ 50mm.

In the case of a long zoom lens where FNC = 0.66 the maximum focal length would be 47mm.

15.6.4.4 Distance to focus on and nearest object distance

Given the farthest distance that must be held in acceptable focus, the lens focal length and aperture and the maximum permissible circle of confusion, the questions may be asked 'what should be the focus distance and how close to the camera can an object be placed to have the same definition as the farthest object?

This can be achieved by doing the same equation twice over, viz:

$$\text{Focus distance} = \frac{\text{Hyperfocaldist.} \times \text{Fardist.}}{\text{Hyperfocaldist.} + \text{Fardist.}}$$

$$\text{Nearest distance} = \frac{\text{Hyperfocaldist.} \times \text{Focusdist.}}{\text{Hyperfocaldist.} + \text{Focusdist.}}$$

or

$$D = (H*fD)/(H + fD)$$

$$nD = (H*D)/(H + D)$$

where D = Focus distance, H = Hyperfocal distance, fD = Far distance and nD = Near distance.

Example: Two objects have to be held in equal focus. One is 13 ft. from the camera, the 50 mm lens is operating at f/4 and the maximum acceptable circle of confusion is 1/500 in. How close can the nearest object be placed and where should the focus be set?

(Note: This simple equation is for 'thin lenses' and should not be used at close focusing distances without making allowances.)

Key Sequence	Example	Display
Enter Hyperfocal distance	40	40
Touch plus	+	40
Enter Far distance	13	13
Find reciprocal (if using a scientific	÷ or = §	53
calculator use the keys marked §)	= or 1/x §	0.0188679
Touch multiply	x	0.0188679
Enter Hyperfocal distance	40	40
Touch multiply	x	0.2452827
Enter Far distance	13	13
Touch equals to find focus distance	=	9.811308

Enter into memory	M+	9.811308
Clear screen	C	0
Enter Hyperfocal distance	40	40
Touch plus	+	40
Recall memory	MR	9.811308
Find reciprocal (if using a scientific	÷ or =§	49.811308
calculator use the keys marked §)	= or 1/x§	0.0200757
Touch multiply	x	0.0200757
Enter Hyperfocal distance	40	40
Touch multiply	x	0.803028
Recall memory	MR	9.811308
Touch equals to find nearest distance	=	7.878755

Answer: Focus distance = 9.8ft and Nearest distance = 7.9ft (9ft 10in, and 7ft 11in).

Computer input
Focus distance (D) = (H*fD)/(H+fD)
Near distance = (H*D)/(H+D)
Let H = 40 and fD = 13
D=(40*13)/(40+13)
(40*D)/(40+D)
9.811320755 and 7.878787879

For greater precision, particularly with large zoom lenses, the following equation is preferable:

$$D = ((H*(fD - FNC))/(H + (fD - FNC))) + FNC$$

$$nD = ((H*(fD - FNC))/(H + (D - FNC))) + FNC$$

where D = Focus distance, H = Hyperfocal distance, fD = Far distance, FNC = Fixed nodal constant and nD = nearest distance.

Focus distance:

Computer input
D = ((H*(fD–FNC))/(H+fD–FNC))+FNC
Let H = 40, fD = 13 and FNC = .16
D = ((40*(13–.16))/(40+13–.16))+.16
9.87990916

Near distance:

((H*(D–FNC))/(H+D–FNC))+FNC
((40*(D–.16))/(40+D–.16))+.16
7.979732034

In the case of a long zoom lens, where FNC = 0.66, the focus distance would be 10 ft. 1 in. and the near distance 8 ft. 3 in.

15.6.4.5 Distance to focus on and farthest object distance

Given the nearest distance that must be held in acceptable focus, the lens focal length and aperture and the maximum permissible circle of confusion, the questions may be asked 'where to set the focus and what is the farthest distance away from the camera that an object can be placed to have the same definition as the nearest object?

This can be achieved by doing the same equation as in 7 above but subtracting, instead of adding, the distance in the divisor or second part of the equation, viz:

$$D = \frac{Hyperfocaldist. \times Neardist.}{Hyperfocaldist. - Neardist.}$$

$$fD = \frac{Hyperfocaldist. \times Focusdist.}{Hyperfocaldist. - Focusdist.}$$

or

$$D = (H{*}nD)/(H - nD)$$

$$fD = (H{*}D)/(H - D)$$

where fD = Farthest distance, H = Hyperfocal distance, nD = Near distance and D = Focus distance.

Example: Two objects have to be held in equal focus. One is 8 ft. from the camera, the 50 mm lens is operating at f/4 and the maximum acceptable circle of confusion is 1/500 in. How far can the farthest object be placed and where should the focus be set?

Key Sequence	Example	Display
Clear memory	MC MC	0
Clear screen	C	0
Enter Hyperfocal distance	40	40
Touch minus	-	40
Enter Near distance	8	8
Find reciprocal (if using a scientific	÷ or = §	32
calculator use the keys marked §)	= or 1/x §	0.03125
Touch multiply	x	0.03125
Enter Hyperfocal distance	40	40
Touch multiply	x	1.25
Enter Near distance	8	8
Touch equals to find focus distance	=	10
Enter into memory	M+	10
Clear screen	C	0
Enter Hyperfocal distance	40	40
Touch minus	-	40
Recall memory	MR	10
Find reciprocal (if using a scientific	÷ or = §	30
calculator use the keys marked §)	= or 1/x §	0.0333333
Touch multiply	x	0.0333333
Enter Hyperfocal distance	40	40
Touch multiply	x	1.333332
Recall memory	RM	10
Touch equals to find farthest distance	=	13.333332

Answer: Focus distance = 10 ft. and Farthest distance ≈ 13.33ft. (9 ft. 10 in. and 13 ft. 4 in.).

Computer input
Focus distance = D=(H*fD)/(H–fD)
Far distance = (H*D)/(H–D)
Let H = 40 and nD = 8
D=(40*8)/(40–8)
(40*D)/(40–D)
10 and 13.33333333

For greater precision, particularly with large zoom lenses, the following equation is preferable:

$$D = ((H^*(nD - FNC))/(H - nD - FNC)) + FNC$$

$$fD = ((H^*(D - FNC))/(H - D - FNC)) + FNC$$

where D = Focus distance, fD = Farthest distance, H = Hyperfocal distance, nD = Near distance and FNC = Fixed nodal constant.

Focus distance:

Computer input
D=((H*(nD–FNC))/(H–nD–FNC))+FNC
Let H= 40, nD = 8 and FNC = .16
D=((40*(13–.16))/(40–8–.16))+.16
D=10.00924623

Far distance:

((H*(D–FNC))/(H–D–FNC))+FNC
((40*(10.00924623–.16))/(40–10.00924623–.16))+.16
13.366835521

Answers: Focus distance ≈ 10ft. and Far distance ≈ 13.37ft. (13ft 4in.)

In the case of a long zoom lens, where FNC = 0.66, the focus distance would be 10 ft. 1 in. and the near distance 8 ft. 3 in.

15.6.5 Focus calculation look-up tables

15.6.5.1 Circles of confusion

TABLE 25. CIRCLES OF CONFUSION
(Each increment represents one stop difference in lens aperture.)

inches	inches	feet	millimeters
1/500	0.002	0.000166	0.05
1/710	0.0014	0.000116	0.036
1/1000	0.001	0.000083	0.025
1/1410	0.0007	0.000053	0.018
1/2000	0.0005	0.000041	0.013

15.6.5.2 Lens focal lengths converted to feet

TABLE 26. LENS FOCAL LENGTHS (mm) EXPRESSED IN FEET

mm	Feet
250	0.82
200	0.66
180	0.59
160	0.52
140	0.46
120	0.39

mm	feet
100	0.328
90	0.295
80	0.262
70	0.23
60	0.197
50	0.164

mm	feet
45	0.148
40	0.131
35	0.115
30	0.098
25	0.082
20	0.66

mm	feet
18	0.059
16	0.052
14	0.046
12	0.039
10	0.033
8	0.026

15.6.5.3 Fixed nodal constant distances

TABLE 27. FIXED NODAL CONSTANT DISTANCES EXPRESSED IN FEET
(For use in depth of field calculations with lens pupil compensation)

Note: The use of a FIXED NODAL CONSTANT is a means to fine tune depth of field calculations and will depend very much upon the design and construction of individual makes and models of lens. There is no hard and fast rule.

However, the FIXED NODAL CONSTANTS listed below are those used in the Samcine Mk II calculator and the various dSam computer calculators and have been in use for many years with much user approval and without complaint and as such they may be taken as a starting point for tests and user experience.

These are round figures only and are not actual nodal positions.

Lens type	feet	meters
Long 35mm type zoom	0.66	0.2
Short 35mm or 16mm type zoom	0.33	0.1
Large fixed focal length	0.16	0.05

15.6.6 Intermediate apertures

15.6.6.1 Whole stop aperture increments

The normal aperture range (f/2, f/2.8/ f/4, etc.) whereby each increment is a halving (or doubling) of exposure is calculated by multiplying (or dividing) the first aperture by the square root of 2 ($\sqrt{2}$) or 1.4142136 and rounding off the result.

Example: What is the next stop smaller than f/8?

Key Sequence	Example	Display
Enter aperture	8	8
Touch multiply	⊠	8
Enter 2	2	2
Touch square root	$\sqrt{\ }$	1.1412136
Touch equals	⊜	11.313708

Answer: ≈ 11.

Note: To calculate 1 stop larger you must *divide* the aperture by $\sqrt{2}$, = 5.656842 ≈ 5.6.

Computer input
Aperture*2^(1/2)
8*2^(1/2)
11.3137085

15.6.6.2 Half stop aperture increments

To calculate a half stop increment it is necessary to multiply (or divide) the previous stop by $\sqrt[4]{2}$ (1.1892071).

Example: What is a half stop smaller than f/8?

Key Sequence	Example	Display
Enter aperture	8	8
Touch multiply	⊠	8
Enter 2	2	2
Touch square root	$\sqrt{\ }$	1.1412136
Touch square root	$\sqrt{\ }$	1.122462
Touch equals	⊜	9.5136569

Answer: ≈ 9.5.

Note: To calculate half stop smaller you must *divide* the aperture by $\sqrt[4]{2}$, = 6.7271713 ≈ 6.7

Computer input
Aperture*2^(1/4)

Note: $\sqrt[4]{2}$ can also be entered as 1.1892071.

15.6.6.3 Third stop aperture increments

To calculate third stop increments it is necessary to multiply (or divide) the previous stop by $\sqrt[6]{2}$ (1.122462).

Example: What is a third stop smaller than f/8?

With a calculator that has a cube root facility this can be done as follows:

Key Sequence	Example	Display
Enter aperture	8	8
Touch multiply	⊠	8
Enter 2	2	2
Touch square root	$\sqrt[2]{\ }$	1.1412136
Touch cube root	$\sqrt[3]{\ }$	1.122462
Touch equals	⊜	8.9796964

Answer: ≈ 9.

Note: To calculate a third stop smaller you must *divide* the aperture by $\sqrt[6]{2}$, = 6.7271713 ≈ 6.7.

With calculators that do not have a cube root facility $\sqrt[6]{2}$ must be entered directly as 1.122462:

Key Sequence	Example	Display
Enter aperture	8	8
Touch multiply	⊠	8
Enter $\sqrt[6]{2}$ as 1.122462	1.122462	1.122462
Touch equals	⊜	8.979696

Answer: ≈ 9.

Computer input
1/3 stop increment = Aperture*2^(1/6)
2/3 stop increment = Aperture*2^(2/6)

Note: $\sqrt[6]{2}$ can also be entered as 1.2246 and $\sqrt[3]{2}$ (2/3 stop) as 1.26.

15.6.6.4 Quarter stop aperture increments

To calculate quarter stop increments it is necessary to multiply (or divide) the previous stop by $\sqrt[8]{2}$ (1.0905077).

Example: What is a quarter stop smaller than f/8?

Key Sequence	Example	Display
Enter aperture	8	8
Touch multiply	⊠	8
Enter 2	2	2
Touch square root	$\sqrt{\ }$	1.4142136
Touch square root	$\sqrt{\ }$	1.1892071
Touch square root	$\sqrt{\ }$	1.0905077
Touch equals	⊜	8.7240619

Answer: ≈ 8.7.

Note: To calculate quarter stop smaller you must *divide* the aperture by $\sqrt[8]{2}$, = 6.7272 ≈ 6.7.

Answer: ≈ 9.

Computer input
1/4 stop increment = Aperture*2^(1/8)
3/4 stop increment = Aperture*2^(3/8)

Note: $\sqrt[8]{2}$ can also be entered as 1.0905.

15.6.7 Macro cinematography

Macro focusing is achieved by increasing the distance between the lens and the film plane or image, very often by the use of additional extension tubes. This system is not suitable for anamorphic or zoom lenses.

Note: Like many other optical calculations shown here, the following equations are for 'thin' lenses and should only be taken as an approximation for multi-element lenses. Some lenses perform better if reversed when the magnification factor becomes greater than 1.

15.6.7.1 Magnification factor

The Magnification factor is required for all macro calculations.

$$\text{Magnification factor} = \frac{\text{Image size}}{\text{Object size}}$$

or

$$M = I/O$$

where I = Image size, M = Magnification factor and O = Object size.

Example: An object 1/2in. wide is to be fill a 35mm Academy frame. What is the Magnification factor?

Key Sequence	Example	Display
Enter Image size (Table 16)	0.831	0.831
Touch divide	÷	0.831
Enter Object size	0.5	0.5
Touch equals	=	1.662

Answer: Magnification factor (M) = 1.662.

15.6.7.2 Lens extension distance

$$\text{Lens Extension distance} = \text{Magnification} \times \text{Lens focal length}$$

or

$$Le = f^*M$$

Put together these become:

$$\text{Lens extension distance} = \text{Lens focal length} \times \left(\frac{\text{Image size}}{\text{Object size}}\right)$$

or

$$Le = f^*(I/O)$$

where f = lens focal length. Le Lens extension and M = Magnification factor.

Example: An object 1/2in. wide is to fill a 35mm Academy frame using a 100 mm lens. How much extension will be required?

Note: The answer will be in the same measurements as the lens focal length. If f is entered in mm the answer will be in mm.

Key Sequence	Example	Display
Enter Image size (Table 16)	0.831	0.831
Touch divide	÷	0.831
Enter Object size	0.5	0.5
Touch multiply	×	1.662
Enter lens focal length	100	100
Touch equals	=	166.2

Answer: The needed lens extension will be 162mm (just over 6.5 in.).

Computer input
f*(I/O)
Let f = 100mm, I= 0.831 and O = 0.5
100*(.381/.5)
166.2

15.6.7.3 Lens to subject distance

As the distance between the lens and the image is increased, so the distance between the lens and the object is decreased.

$$\text{Lens to object distance} = \frac{f}{M}$$

or

$$\text{Lens to object distance} = f/M$$

15.6.7.4 Stop correction

When shooting macro scenes it is necessary to correct the lens aperture setting to compensate for the image magnification.

$$\text{Corrected stop} = \frac{OS}{(M+1)}$$

or

$$\text{Corrected stop} = OS/(M+1)$$

where OS = the Old Stop and M = the Magnification factor.

Example: An object 1/2in. wide is to fill a 35mm Academy frame using a 100 mm lens. The exposure meter reads a setting of f/8. At what stop should the lens be set? The Magnification factor has already been calculated to be 1.662.

Key Sequence	Example	Display
Enter Magnification factor	1.662	1.662
Touch plus	+	1.662
Enter 1	1	1
Find reciprocal (if using a scientific	÷ or = §	2.662
calculator use the keys marked §)	x or 1/x §	0.3756574
Touch multiply	x	0.3756574
Enter Old Stop setting	8	8
Touch equals	=	3.0052592

Answer: The lens stop would need to be set to f/3.

Computer input
OS/(M+1) or OS/((I/O)+1)
Let OS = 8, and M = 1.662
8/(1.662+1)
3.005259204

15.6.8 Diopters

Diopters are simple supplementary lenses placed in front of a camera lens to enable the lens to be focused more closely than is possible by the available extension.

They are particularly suitable for use with zoom lenses as they do not affect focus while the lens is being zoomed, as does close focusing by extension. They are equally useful with anamorphic lenses due to the limited close focus capability of such lenses and for split diopter usage to take advantage of the wide screen.

In addition to enabling close focusing diopters to change the focal length of a lens, a positive diopter making the combined focal length longer than the original.

In theory, a 1 meter focal length supplementary lens ('+1 diopter' focal length) placed in front of a camera lens focused at infinity will change the point of focus to 1 meter distance. A +2 diopter will change the point of focus to 1/2 meter, and so on.

In practice this is not exactly so because modern cine lenses, especially zoom lenses, are physically very long and this affects the power of the diopter. For this reason the following calculations can only be taken as a guide.

Note: Because both the focal length of lenses and of diopter powers are always quoted in metric units it is most convenient to make all calculations in metric units and to convert to or from feet and inches as necessary.

15.6.8.1 Diopter power

The power of a positive diopter is the reciprocal of its focal length (in meters) viz:

$$+\text{Diopter power} = \frac{1}{\text{focal length}} \text{ or } 1/f$$

In practice, because the focal length of a lens is almost always described in millimeters this formula becomes:

$$+\text{Diopter power} = \frac{1000}{\text{focal length}} \text{ or } 1000/f$$

If the focal length of a lens is not known it can most easily be found, with sufficient accuracy for all practical purposes, by holding it in front of a white wall or other suitable surface and creating an in-focus image of a distant bright object. The focal length may also be calculated:

$$\text{Focal length (mm)} = \frac{1000}{\text{diopter power}} \text{ or } 1000/DP$$

15.6.8.2 Change of focal length

When two lenses are used together and one is a normal lens and the other a 'diopter' supplementary lens the combined focal length may be calculated:

$$\text{Combined focal length} = \frac{\text{focal length (mm)} \times 1000}{(\text{focal length} \times \text{diopter power} + 1000)}$$

or

$$CFL = f{*}1000/(f{*}DP + 1000)$$

where CFL = Combined focal length, f = Lens focal length and DP = Diopter Power.

Example: A +1.25 diopter is to be used in front of a 100mm lens. What will be the combined focal length?

Key Sequence	Example	Display
Clear Memory	MC MC	0
Enter lens focal length	100	100
Touch multiply	x	100
Enter Diopter Power	1.50	1.50
Touch plus	+	150
Enter 1000	1000	1000
Put into memory	M+	1150
Clear screen	C	0
Enter lens focal length	100	100
Touch multiply	x	100
Enter 1000	1000	1000
Touch divide	÷	100000
Recall memory	MR	1150
Touch equals	=	86.956521

Answer: ≈ 87mm.

Computer input
f*1000/(f*DP+1000)
Let f = 100 and DP = 1.5
100*1000/(100*1.5+1000)
86.95652174

15.6.8.3 Focus distance with a diopter

If a lens is focused on infinity and a diopter lens is placed in front of it the resultant point of focus will be:

$$\textit{Combined focus distance with lens set on infinity} = \frac{1}{\textit{diopter power}}\ \textit{meters}$$

When the lens is focused on an intermediate distance the combined point of focus becomes:

$$\textit{Combined focus distance with lens set closer than infinity} = \frac{\textit{Lens scale distance}}{\textit{Lens scale distance} \times \textit{diopter power} + 1}\ \textit{meters}$$

or

$$CPF = LSD/(DP*LSD+1)$$

where CPF = Combined point of focus, LSD = Lens scale distance and DP = Diopter power.

Example: The nearest a particular zoom lens will focus down to is 1.5 meters. If a +1.5 diopter is used what will be the combined focus range?

Far distance:

Key Sequence	**Example**	**Display**
Enter 1	1	1
Touch divide	÷	1
Enter diopter power	1.5	1.5
Touch equals	=	0.666666

Near distance:

Key Sequence	**Example**	**Display**
Clear memory	MC MC	0
Enter lens scale distance (meters)	1.5	1.5
Touch multiply	×	1.5
Enter diopter power	1.5	1.5
Touch plus	+	2.25
Enter 1	1	1
Put into memory	M+	3.75
Clear screen	C	0
Enter lens scale distance	1.5	1.5
Touch divide	÷	1.5
Recall memory	MR	3.75
Touch equals	=	0.4

Answers: Focus range ≈ 0.66 - 0.4 meters.

15.6.8.4 Needed diopter

A useful accessory frequently used by cinematographers, especially when filming in the wide screen and anamorphic formats, is the split diopter; a portion of a diopter lens placed over one side of a taking lens to bring into focus a part of the scene set closer to the camera than could normally be held by normal depth of field. Split diopters create two planes of focus.

$$\textit{Needed diopter} = \frac{1}{\textit{distance with diopter}} - \frac{1}{\textit{distance without diopter}}$$

or

$$ND = (1/DND) - (1/DWD)$$

where ND = Needed diopter, DND = distance without diopter and DWD = distance with diopter.

Example: A split diopter is to be used on a scene where one person is 2.8 meters from the screen and the other is at 0.7 meters. The lens is to be focused on 2.8 meters. What power diopter will be required for the other person?

Key Sequence	Example	Display
Clear memory	MC MC	0
Enter 1	1	1
Touch divide	÷	1
Enter distance without diopter (meters)	2.8	2.8
Put into memory	M+	-0.3571428
Clear screen	C	0
Enter 1	1	1
Touch minus	÷	1
Enter distance with diopter (meters)	0.7	0.7
Touch minus	-	1.4285714
Recall memory	MR	0.3571428
Touch equals	=	1.0714286

Answer: ≈ +1 diopter.

Notes: As already noted, all the above diopter calculations are less accurate for large cine lenses than they are for 'thin' lenses unless a compensating factor is added to allow for the size of the lens.

All distances are in meters.

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